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ATTACHMENT 1

FOR

PEPE FINAL REPORT:

PEPE FUNCTIONAL SIMULATION CALIBRATION MODEL

AND

SYSTEM VERIFICATION MODEL DOCUMENTATION

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TECH MEMO

a working paper

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PEPE FUNCTIONAL SIMULATION

CALIBRATION MODEL AND SYSTEM VERIFICATION MODEL DESCRIPTIONS

Real-Time Advanced Data Processing

Parallel Element Processing Ensemble

[redacted]

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1.0 INTRODUCTION

The PEPE Simulation Project has had the responsibility of validating the design of the MSI PEPE by functional simulation. This validation was achieved by demonstrating that the performance characteristics of the MSI PEPE are superior to those of the IC design used in the PHSD demonstrations. Toward achieving design validation, two functional simulation models were constructed; a Calibration Model and a System Verification Model. The purpose of this document is describe the functions performed by the action sequence chains that comprise these two models.

The Calibration Model is a functional simulation model of the PHSD tactical process, as it was designed and operated for the PHSD demonstrations. The purpose of the Calibration Model is to adjust the simulation parameters to produce simulator results equivalent to the PHSD experimental data as a first step to validating the System Verification Model. The System Verification Model is a functional simulation model of the PHSD tactical process designed to operate on the MSI PEPE Hardware configuration. The purpose of the System Verification Model is to obtain performance data for the MSI Model PEPE for validating the MSI Model design. Both models were constructed to operate under the supervision of the PEPE Functional Simulation System (PEPSIE) described in, TM-HU-44/400/00, User's Manual for PEPE Functional Simulation System and PEPE Process Construction System. Both models used the CDC ENLODE2 data management system for data base definition and run time data management functions.

2.0 CALIBRATION MODEL

The Calibration Model consists of a PHSD tactical software system, PHSD tactical system control, and radar, threat, interceptor track, and interceptor farm models. In the actual PHSD implementation, the functions performed by the radar, threat, interceptor track, and interceptor farm models were performed by the SACS simulation system located at General Research Corporation, Santa Barbara, California. The PHSD tactical software system and tactical control were performed on real and simulated processors at Bell Telephone Laboratory, Whippany, New Jersey.

2.1 CALIBRATION MODEL HARDWARE

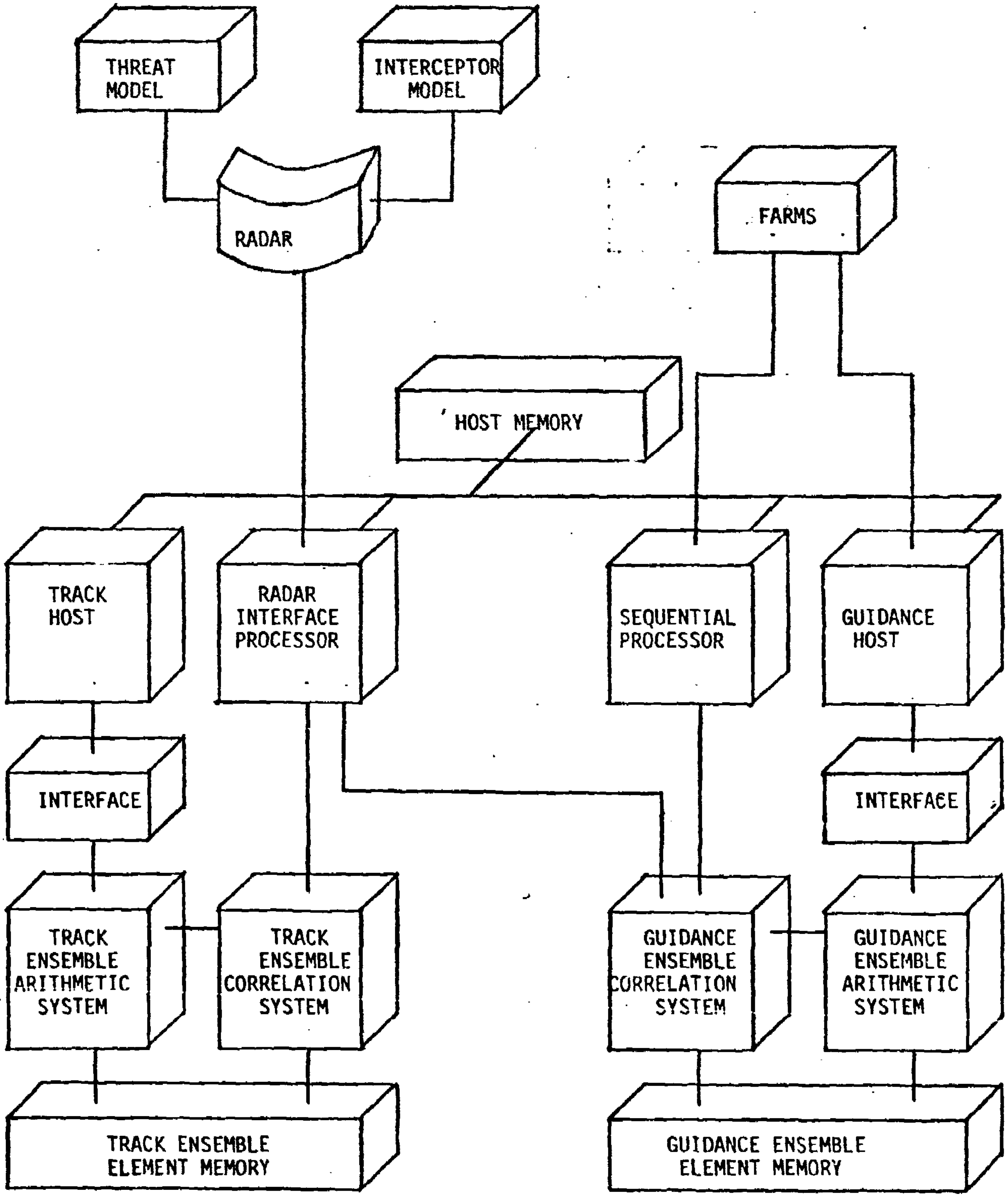
The Calibration Model tactical system hardware (Figure 1) is a four-processor, CLC-like multiprocessor with a shared Host memory. Two processors serve as Hosts for PEPE ensembles. One PEPE Host ensemble with 100 elements is dedicated to target tracking tasks; the other with 16 elements is dedicated to intercept planning, tracking, and guidance. The Host processors are required for PEPE Arithmetic Systems because the IC Model PEPE Arithmetic Control Units have no stored program capability. Parallel instructions must be sent from the Host to PEPE; sequential instructions are executed in the Host. Therefore, these combinations are treated as one logical unit. The IC Model PEPE Correlation System does have a stored program capability and can operate independent of its "Host", and therefore can be treated as separate facilities. The remaining two processors, the Radar Interface Processor (RIP) and the Sequential Processor, are used for sequential tasks. This hardware is represented in the model by six PEPSIE facilities which are seized by tactical tasks operating in the processors.

The Calibration Model radar and interceptor farms are represented by PEPSIE action sequence chains only. Since these functions are not being calibrated, there is no necessity to gather data on hardware usage.

2.2 CALIBRATION MODEL SOFTWARE

The following description of the Calibration Model software consists of a description of how tactical action sequence chains were constructed and operated and a short description of each action sequence

CALIBRATION MODEL



chain in the model. These descriptions are not intended to completely describe the PHSD implementation being modeled; rather they attempt to point out any differences in implementation between the system being modeled and the model. (For a complete summary of the system being modeled, see Section 6, Volume 2, Part 1 of the Ballistic Missile Defense Advanced Development Program Advanced Data Processing Report dated September 30, 1971, prepared by Bell Laboratories.)

2.2.1 Tactical Action Sequence Chain Construction

Tactical action sequence chains consist of two parts; data manipulation code and a time model. The data manipulation code ensures that the model programs operate in the same sequence and obtain the same results as programs in the system being modeled. The time model calculates the amount of time it takes for a program to operate.

Time models for tactical routines in the Calibration Model were constructed by classifying all instructions into basic categories. Then the actual code for each program in the system being modeled was examined and the number of instructions in each basic category in each program region was counted. If a region was conditionally operated, its inclusion in the time model was also conditional. The time models were then installed in calibration model action sequence chains with counters and flags embedded in the data manipulation code to indicate which regions operated each time a program was run.

2.2.2 Tactical Action Sequence Chain Operation

During system initialization, average operate time for each basic class of instruction is set. These times were computed for PEPE instruction classes based on the hardware design goal speeds and on the actual mix of instructions within each category operated during PHSD runs. For sequential processor instructions, time was based on the theoretical speed of processors used in PHSD runs. These times are then combined with action sequence chain time models to compute operate times for each region in the action sequence chain.

During each operation of an action sequence chain, simulation initialization is performed first. This seizes any required facilities and clears the counters and flags which indicate activity for each operation. Next the data manipulations which drive the tactical system are performed. This includes flagging events and making counts to which the time model is sensitive. Then the actual delay for this operation is computed by combining program activity with computed delays for program regions. The seized facilities are held for this amount of time by calling the PEPSIE delay function one or more times. Finally tactical and simulation terminal code is performed. The tactical code includes any actions which cannot be done until a routine is ready to finish, such as enabling successor routines. Simulation terminal code triggers any hardware activated successor routines, releases seized facilities, and returns control to PEPSIE.

2.2.3 Action Sequence Chain Description

Following are descriptions of the tactical action sequence chains which are used in the Calibration Model. The action sequence chains are grouped in categories determined by the hardware facility or facilities on which they operate. This mapping is shown in Figures 2 and 3 for the farm processors in the Model.

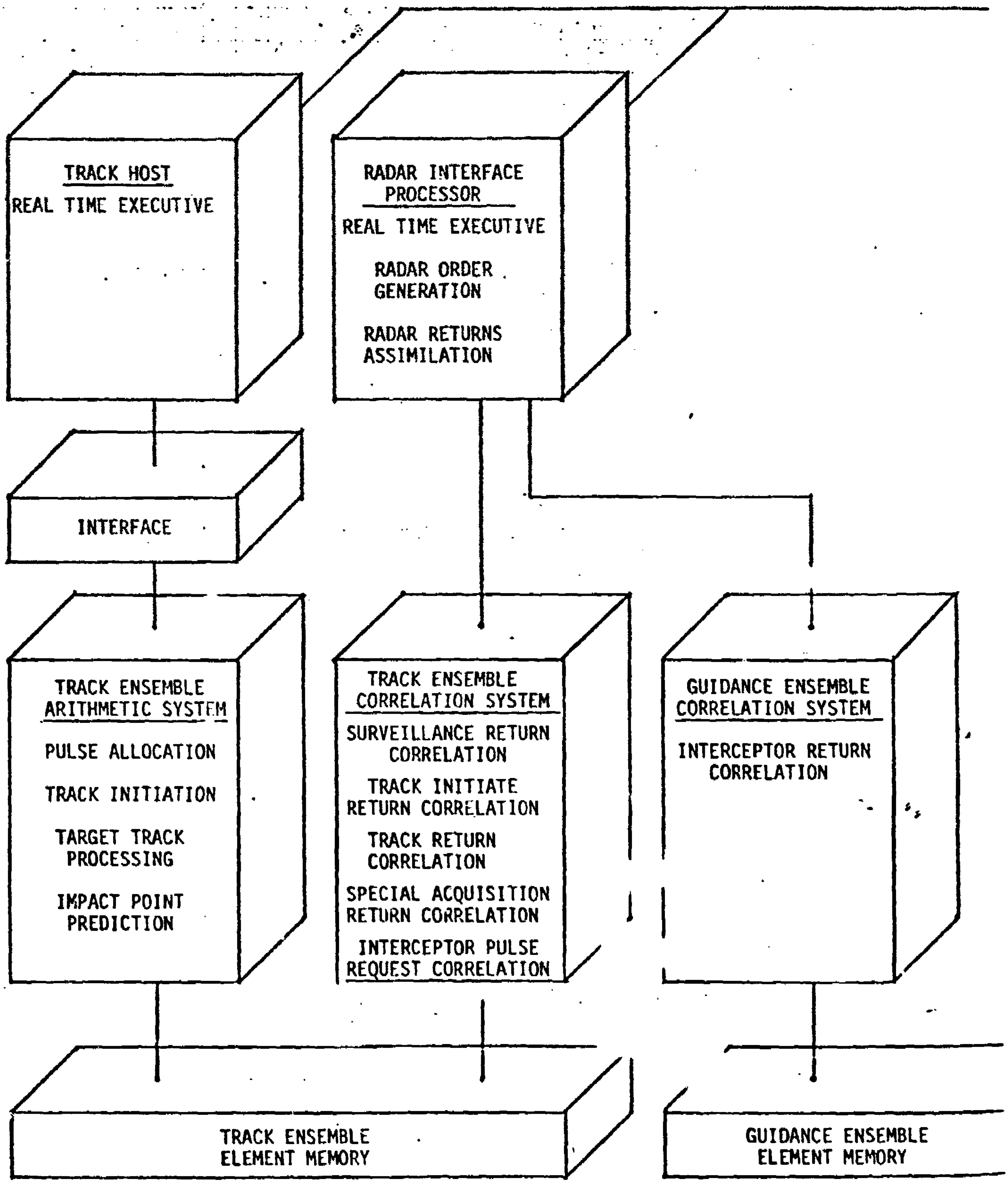


FIGURE 2. Tactical Action Sequence Chain Mapping for the TRACK and RADAR Interface Processor

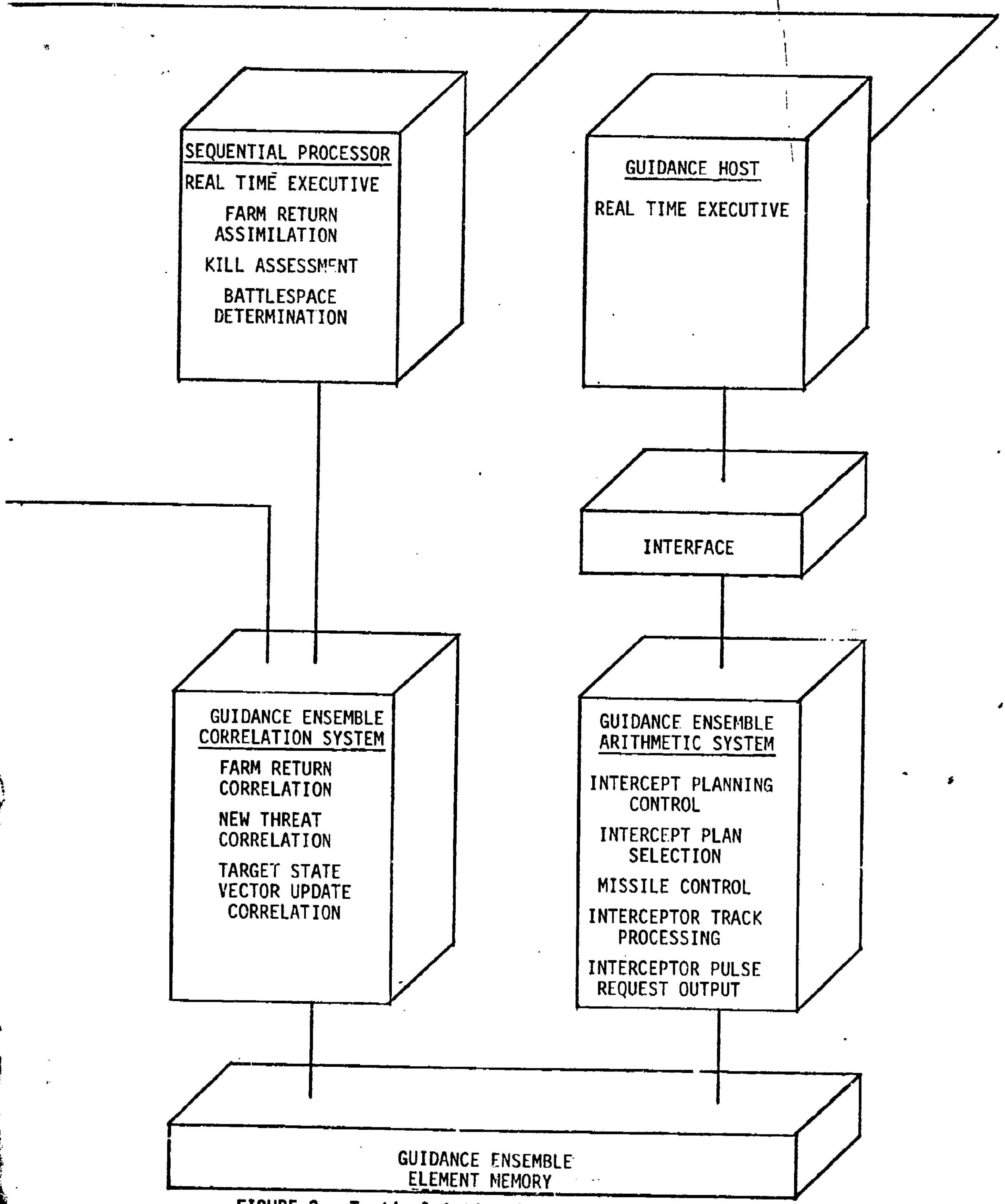


FIGURE 3. Tactical Action Sequence Chain for the

Action Sequence Chains	Functions Performed	Comments
2.2.3.1 Parallel Routines - Track Host/Track Ensemble Arithmetic System		
Pulse Allocation (ALLOC)	1. Schedule pulses for all targets and interceptors in track along with pulses necessary for surveillance, and pass scheduled data to the Radar Order Generation function. 2. Enable Target Track Processing, Track Initiation, Pulse Allocation, Interceptor Track Processing, Missile Control, and Interceptor Pulse Request Output to operate next cycle. Cycle length is determined by track rate and the amount of time it takes to process a return, allocate a pulse, and deliver the orders for that pulse to the radar.	The functions performed are the same as those performed in the system being modeled although the amount of data passed is smaller because of the simplified geometry of the threat and interceptor models.
Track Initiation (TRKINI)	1. Process initial track returns for each target. If too much time elapses before two valid returns are received, drop the target. 2. When a second valid return is received, initialize target state and make track elibible for processing by Target Track Processing.	The functions performed are the same as those performed in the system being modeled.

Action Sequence Chain	Functions Performed	Comments
Target Track Processing (TRKPRO)	1. Use newly received radar returns to update predicted position of objects in track. 2. Monitor track quality and, if necessary, initiate processing procedures to reacquire lost objects. 3. Enable Impact Point Prediction when one or more objects require deghosting or threat determination procedures. 4. Enable Target State Vector Correlation to pass newly updated target track data to the Guidance Ensemble. 5. Coordinate with Intercept Planning Control in the Guidance Ensemble when threatening objects are dropped in the Track Ensemble.	The prediction function is a simplified version of the Kalman filter used to update the target state vector. The other functions are basically the same as those performed in the system being modeled.

Action Sequence Chain	Functions Performed	Comments
Impact Point Prediction (IMPPT)	1. Detec ghost tracks by linearly predicting older tracks to the position of the new track and comparing positions. If the new track is sufficiently close to an object in track, it is a ghost track and is dropped.	Threat discrimination in the system being modeled is an iterative process in which only one iteration is performed for each operation of IMPPT.
	2. Discriminate between threatening and non-threatening objects, and for threatening objects, determine the type of attacker.	The simplified geometry of the model precludes an actual determination of the number of iterations required for any object. Therefore, to compute the number of iterations required for each object, the model uses an algorithm based on the observed experience in the system being modeled.
	3. Enable New Target State Vector Correlation to initialize an element in the guidance ensemble for a newly detected threatening object.	

Action Sequence Chain	Functions Performed	Comments
2.2.3.2 Sequential Routines - Radar Interface Processor		
Radar Order Generation (GENER)	1. Process all pulses assigned to a radar frame and produce detailed orders to point the radar, transmit pulses, and receive returns. Continue processing frames until all frames in a block have been processed. 2. Pass detailed radar orders to the Radar Clock Chain and pass any farm orders to the Farm Model. 3. Enable Radar Return Assimilation to process returns from the current block of orders and enable itself to make up the next block.	In the system being modeled, functions 2 and 3 were performed by a Data Link interface program which was not required in the model. Function 1 in the model is more complex because, in the system being modeled, producing detailed orders was done by the SACS simulation system.

Action Sequence Chain	Functions Performed	Comments
Radar Return Assimilation (ASSIM)	1. Process all radar returns in one block of data. Enable one of the track correlation routines to process each track return. 2. Set up communication for the generation of a verify pulse after receipt of a positive search return. 3. Perform bulk velocity filtering on Search/verify pairs and enable Surveillance Return Correlation to process any valid pairs. 4. Enable Farm Return Assimilation to process any farm returns received from the Farm Model.	In the model, low signal amplitude checks have been eliminated. In the system being modeled, function 4 was performed by the data link interface program. The other functions are basically the same in both systems.

Action Sequence Chain	Functions Performed	Comments
2.2.3.3	Correlation Routines - RIP/Track Ensemble Correlation System	
Surveillance Return Correlation (SURCO)	1. Correlate each new search/verify pair with objects currently in track to determine if the new target is already known to the system. The correlation is a single gate correlation on search sector and beam position, range, and range velocity. 2. If no correlation occurs, activate an empty PEPE element, initialize it, and request a track pulse for the object. 3. If correlation occurred, use return to update any matched non-threatening object being tracked by surveillance returns.	Due to the simple geometry of the model, no ghost tracks can fail the real correlation tests. Therefore a random factor has been introduced to allow a number of ghosts to enter the system. The number reflects the actual experience in the system being modeled.

Action Sequence Chain	Functions Performed	Comments
Track Initiate Return Correlation (TRICO)	1. Check for ghost tracks by correlating positive track initiate returns with other objects in track. 2. If correlation occurs, drop the newer object from the system. 3. If no correlation occurs, place return in object's PEPE element by performing exact match correlation on object identification number.	Since no ghost track can fail the correlation tests, a random factor has been introduced to allow a number of ghosts to remain in the system. This allows the deghosting function of Impact Point Prediction to operate in the manner observed in the system being modeled.
Track Return Correlation (TRKCO)	Correlate positive and negative track returns and negative track initiate returns by performing an exact match correlation on object identification number. Place data from the return in the object's PEPE element memory.	
Special Acquisition Return Correlation (SASCO)	Correlate positive and negative special acquisition returns by performing an exact match correlation on object identification number. Place data from the return in the object's PEPE element memory.	

Action Sequence Chains	Functions Performed	Comments
Interceptor Pulse Request Correlation (IPRCO)	Activate an empty Track Ensemble PEPE element and store in it all data necessary to allow Pulse Allocation to make up a pulse request for an interceptor. (When the pulse is scheduled, Pulse Allocation sets element status to empty and it becomes available for another interceptor pulse request.)	

2.2.3.4 Correlation Routine - RIP/Guidance Ensemble Correlation System

Interceptor Return Correlation (INTCO)	Correlate positive and negative interceptor returns by performing an exact match correlation on missile identification number. Place data from the return in the interceptor's PEPE element memory.	

Action Sequence Chain	Functions Performed	Comments
2.2.3.5	Parallel Routines - Guidance Host/Guidance Ensemble Arithmetic System	
Intercept Planning Control (INCTL)	1. Monitor the intercept plan status of all threatening objects. 2. Enable Battlespace Planning and pass data to it when an unplanned intercept or one which requires replanning is detected. 3. Check continued feasibility of planned intercepts just before interceptor launch time. 4. Enable Kill Assessment and pass data to it when a burst status is detected. 5. Coordinate with Target Track Processing in the Track Ensemble when threatening objects are dropped in the Guidance Ensemble.	The simplified geometry of the model insures that the intercept feasibility check is always successful. Since this reflects the experience with the system being modeled, no attempt has been made to introduce failures at this point.

Action Sequence Chain	Functions Performed	Comments
Intercept Plan Selection (INTSEL)	1. Select earliest intercept point for a threatening object. This calculation is based on earliest intercept time for one or both farms provided by Battlespace Planning, the stockpile balancing algorithm, and fractricide resolution. 2. Drop any objects for which an intercept point cannot be established. 3. Enable INTSEL to operate again if all plans under consideration have not been resolved.	Fratricide resolution in the system being modeled is an iterative process which requires another operation of INTSEL if any intercept plan under consideration fails the fratricide test. Since the simplicity of the model's geometry precludes a deterministic representation of fratricide resolution, an algorithm based on the number of active intercept plans, the number of fratricides previously found and a constant based on type of threat is used to determine if fractricide has been resolved for each object being considered.

Action Sequence Chain	Functions Performed	Comments
Missile Control (GIDNC)	1. After breakwire,* initialize interceptor data sets and schedule first radar pulse. 2. Upon receipt of a radar return, determine whether it is time to send a discrete command and schedule it if it is time. 3. Upon receipt of a radar return, schedule the next radar pulse. 4. Monitor interceptors to determine when staging, missile failure, or burst occur.	Since the geometry in both threat and interceptor models is so simple, there is no need to compute guidance commands for interceptors. However, if there are missiles being guided, the time to do these computations is included in run time.
Interceptor Track Processing (MTTRK)	Update interceptor range on receipt of a positive radar return.	Simplified version of algorithm used to update missile state vector.

*Breakwire is the exact time of missile (interceptor) launch.

Action Sequence Chain	Functions Performed	Comments
Interceptor Pulse Request Output (IPREX)	1. Monitor interceptors in pre-launch status and make up Missile Launch Sequence Requests to be sent to the farm at a specified interval before launch time. 2. Monitor in-flight interceptors and cause pulse requests to be transferred to the track ensemble when requested. Enable Interceptor Pulse Request Correlation in the track ensemble to process each request. 3. Enable Intercept Planning Control on a cyclic basis.	Functions performed are the same as those performed in the system being modeled.

2.2.3.6 <u>Sequential Routines - Sequential Processor</u>

Farm Return Assimilation (FRMAS)	1. Modify farm stockpile counts based on data contained in farm return messages. 2. Enable Farm Return Correlation to process all farm return messages except stockpile update messages.	Functions performed are the same as those performed in the system being modeled.

Action Sequence Chain	Functions Performed	Comments
Battlespace Planning (BTLSPC)	1. Determine whether one or two farms are to be considered. 2. Determine whether battlespace is available for an interceptor from the selected farm. If none available request that the target be dropped. If battlespace is available, enable Intercept Plan Selection to plan the intercept.	Battlespace planning in the model is a simplified version of the process performed in the system being modeled. It uses an algorithm based on observed system performance to compute the number of iterations of target state prediction necessary to compute earliest intercept time.
Kill Assessment (INQEST)	For radar attackers, determine if the target was successfully intercepted after burst has occurred. If intercept was successful, request that the target be dropped. If not successful, flag target for replanning.	Kill assessment in the model is based on a random number comparison with kill threshhold. The threshhold is set to a number which reflects actual performance in the system being modeled.
2.2.3.7	Correlation Routines - Sequential Processor/Guidance Ensemble Correlation System	
Farm Return Correlation (FRMCO)	Correlate data from farm return messages with interceptors by performing an exact match correlation on missile identification number.	Functions performed are the same as those performed in the system being modeled.

Action Sequence Chain	Functions Performed	Remarks
New Threat Correlation (NSVCO)	Store data pertaining to a newly classified threatening object into an empty element in the Guidance Ensemble.	Function performed is the same as that performed in the system being modeled although not as much data is passed.
Target State Vector Update Correlation (TSVCO)	Correlate target state vector data passed from the Track Ensemble with targets in the Guidance Ensemble by performing an exact match correlation on object identification number.	Function performed is the same as that performed in the system being modeled although not as much data is passed.
2.2.3.8 PHSD Tactical System Control		
Real-Time Executive (SIMEX)	Determine which processor has just completed operation or is idle and initiate operation of the Task Allocator to determine if there is a task ready to operate in that processor. If there is, initiate operation of that task. If there is not, arrange to operate SIMEX again when the next task in that processor is scheduled to begin operation.	Although only one routine exists, theoretically each of the four processors has a copy of SIMEX which controls operations in that processor. In the system being modeled, in addition to the control function SIMEX was responsible for system timing. In the model, this function is performed by the PEPE Simulation Executive (PEPSIE).

Action Sequence Chain	Functions Performed	Comments
Task Allocator (TALLOC)	For the specified processor, select the scheduled task having the highest priority whose enablement time has been reached. If there is no task ready to operate, TALLOC passes the earliest scheduled operate time to SIMEX.	Does not perform consistency scan of all enablements for the selected processor. This routine also theoretically exists in all four processors and is operated as a subroutine by SIMEX.
Task Enablement (ENABLE)	Accept task enablements from tactical routines and add them to an enabled task list for the processor in which the enabled task operates.	This routine theoretically exists in all four processors and is operated as a subroutine by tactical tasks. The function performed is the same as that performed in the system being modeled.
2.2.3.9 Radar Model		
Radar Clock Chain (RDRCLK)	Processe radar orders received from the Radar Order generation function. Upon receipt of a transmitter on order, trigger operation of either the Threat Model or the Interceptor Model to check for possible returns. On receipt of a receiver off order, transmit positive or negative radar returns to the Radar Return Assimilation function.	Performs functions which were done by SACS simulation system in the system being modeled.

Action Sequence Chain	Functions Performed	Comments
2.2.3.10 <u>Threat Model</u>		
Initial Threat Processing (THRT)	Search list of threatening objects for any objects whose search sector and beam position are equal to the current position of the radar. If any are found, update range, compute time at which a return will be received at the radar and trigger Threat Return Processing to operate at that time.	In the model, threatening objects are described by search sector and beam position, range, range closing rate and cross section. Search sector and beam position and range closing rate do not change. This is a gross simplification of the threat geometry used in PHSD but is sufficiently complex to allow construction of threats which behave like threats used in PHSD.
Threat Return Processing (THRTRTN)	Determine if the radar is in receive mode and if its current pointing angle (determined by search sector and beam position) is equal to the pointing angle required to see the return which will arrive at this time. If it is, create a positive radar return.	

Action Sequence Chain	Functions Performed	Comments
2.2.3.11 Interceptor Model		
Initial Interceptor Processing (INTPRO)	Search active interceptor list for specified interceptor. If found determine if burst or self-destruct has occurred. If not, compute time at which a return will be received at the radar and trigger Interceptor Return Processing to operate at that time.	The interceptor model is extremely simple. Each interceptor is launched in the same search sector and beam position as its target and instantly reaches a constant speed.
Interceptor Return Processing (INTRTN)	1. Determine if the radar is in receive mode and, if it is, determine if a return is expected at the current time for the specified interceptor. If it is, create a positive radar return. 2. If a positive return is created, process any discrete command contained in the radar order.	

Action Sequence Chain	Functions Performed	Comments
2.2.3.12 <u>Farm Model</u>		
Farm Input Processing (FRMIN)	1. Process farm communication messages received from tactical system, creating or modifying entries in the active interceptor list as required. 2. Trigger Farm Output Processing to make up replies.	
Farm Output Processing (FRMOUT)	1. Search active interceptor list for farm return messages to be made up at the current time and pass them to the tactical system. 2. Delete entries in the active interceptor list for cancelled interceptors.	

3.0 SYSTEM VERIFICATION MODEL

The System Verification Model was constructed by perturbing the Calibration Model in order to map the PHSD process onto the newly designed PEPE MSI hardware/Host configuration.

3.1 SYSTEM VERIFICATION MODEL HARDWARE

The System Verification Model tactical system hardware (Figure 4) consists of a single processor Host (CDC 7600), a Radar Interface Computer, and one 200-element MSI PEPE ensemble. The PEPE ensemble consists of an Arithmetic System, an Associative Output System, a Correlation System, and a shared Element Memory. The Host, RIC, and PEPE Arithmetic Control Unit are interruptable; the PEPE Associative Output Control Unit and Correlation Control Unit are not. These hardware elements are represented in the model by six PEPSIE facilities; one each for the Host, the RIC, the three PEPE processing systems, and a shared facility representing Element Memory. In this model, interrupts of the Arithmetic Control Unit by the Correlation Control Unit and the Associative Output Control Unit and the effect of shared Element Memory on memory access time are modeled.

3.2 SYSTEM VERIFICATION MODEL SOFTWARE

In the following description, action seqeunce chains are described in terms of changes made in converting from the Calbiration Model to the System Verification Model. Tactical action sequence chains are grouped in categories determined by the hardware facility on which they operate (Figure 5).

One major change is the incorporation of SIM2 version of the BMD Real-Time Operating System in the model. Since this system is fully described in TM-HU-043/200/00, Software Design Specification for Real-Time (BMD) Operating System, no attempt is made to describe it here.

The Radar Model, Threat Model, Interceptor Model, and Farm Model are functionally unchanged. Communication between these models and the tactical system is modeled in much greater detail and with more accuracy than was the case in the Calibration Model.

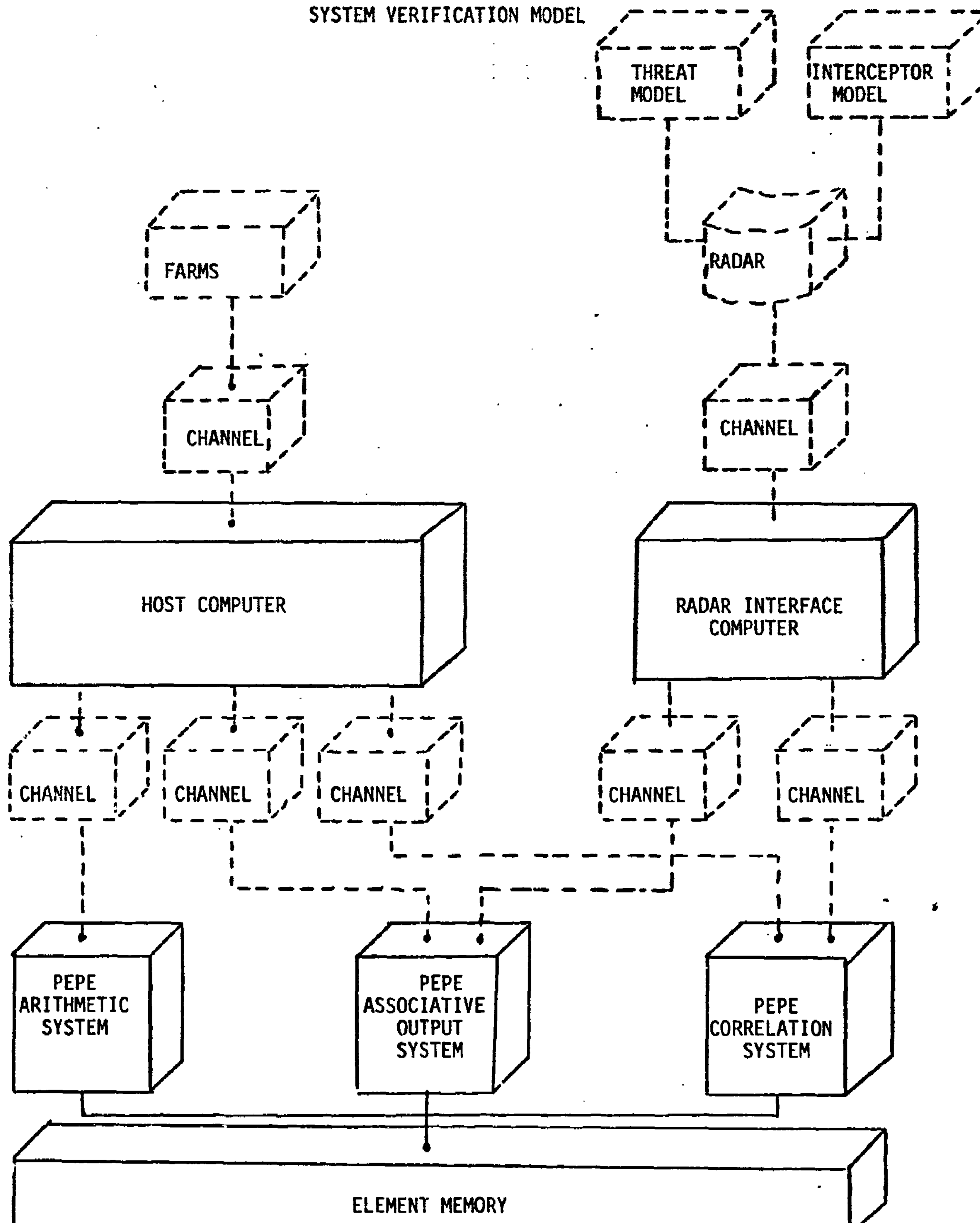


FIGURE 4. MSI PEPE/HOST Hardware Configuration

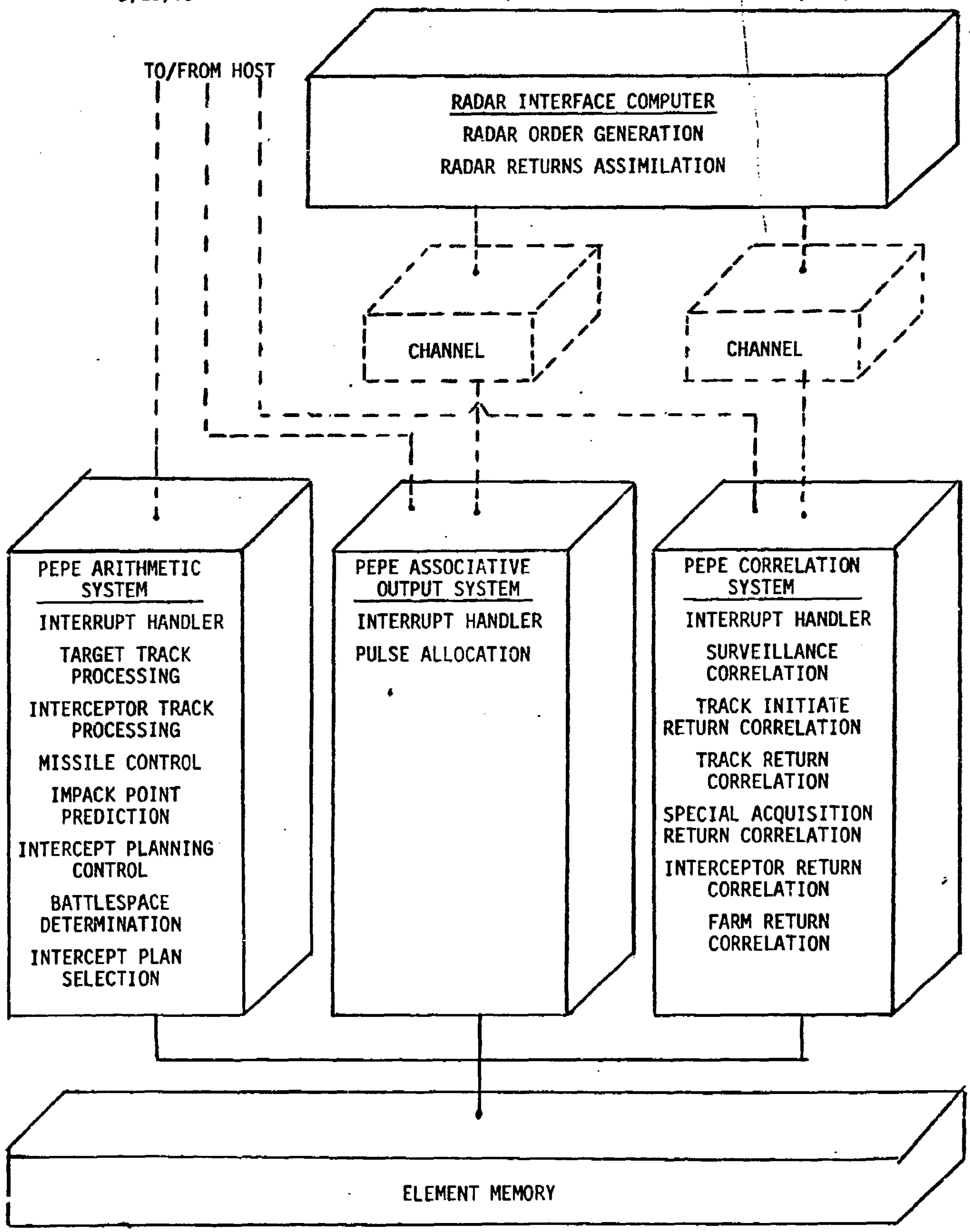


FIGURE 5. MSI PEPE/HOST Tactical Function Software Configuration

3.2.1 Sequential Routines - Host Computer

PEPE Starter Routines (HOST) - (new routine)

Scheduling of PEPE Arithmetic System and PEPE Associative Output System is handled through the Host. When it is time to operate a PEPE routine, one of the PEPE Starter Routines is operated. This routine makes up a message which is sent to the proper PEPE controller where it is processed by an interrupt handler.

Farm Message Initial Processing (FARMM) - (new routine)

FARMM operates each time a farm communication messages is received from PEPE. It moves the message from an input buffer where it was stored by the BMDOS to a Host data set where it will be processed by Farm Communication Control.

Farm Communication Control (IPREX) - (modified)

IPREX operated in the Guidance Ensemble Arithmetic System where it monitored interceptors to determine if a farm communication or pulse request was required. The pulse request function has been incorporated in Pulse Allocation. The farm communication function is now accomplished by monitoring farm messages passed from PEPE. These messages are passed to the Farm Model, and a Missile Launch Sequence Request is initiated at a specified period before launch time. IPREX operates on a cyclic basis.

Farm Return Assimilation (FRMAS) - (modified)

FRMAS operated in the Sequential Processor. It is functionally unchanged but has been modified to use the new data communication procedures both in receiving the data from the farm and passing it to PEPE.

3.2.2 Sequential Routines - Radar Interface Computer

Interrupt Handler (RIC) - (new routine)

On receipt of messages, RIC schedules programs which operate in the Radar Interface Computer. Radar Order generation is operated when a pulse allocation message is received from the PEPE Associative Output System; Radar Return Assimilation is operated when returns are received from the radar.

Radar Order Generation (GENER) - (modified)

GENER no longer handles farm communication messages and no longer schedules itself and Radar Return Assimilation. GENER has also been modified to use the new data communication procedures.

Radar Return Assimilation (ASSIM) - (modified)

ASSIM no longer handles farm communication messages and has been modified to use the new data communication procedures both in receiving returns from the radar and sending them to the PEPE Correlation System.

3.2.3 Parallel Routines - PEPE Arithmetic System

The PEPE Arithmetic System consists of an Arithmetic Control Unit (ACU) and an Arithmetic Unit (AU) in each PEPE element. The new ACU has program and data memory; therefore, it no longer requires a Host computer to send instructions to it. Also, it is interruptable. This feature allows low priority tasks to be operated as background tasks. Operation of these tasks is started when the ACU is idle, interrupted when a high priority task is scheduled, and resumed when all scheduled high priority tasks have completed operation. The high priority tasks are Target Track Processing, Interceptor Track Processing, and Missile Control. In addition to scheduled tasks, the PEPE Arithmetic System also performs floating point computations requested by tasks operating in the PEPE Correlation System and the PEPE Associative Output System. These computations are high priority and interrupt any task operating in the Arithmetic System except the Interrupt Handler.

Interrupt Handler (ACU) - (new routine)

Upon receipt of a message, ACU schedules a task to be run in the PEPE Arithmetic System. If the system is idle, operation of the task is immediately initiated. If a low priority task is operating and the new task is high priority, operation of the low priority task is suspended. The low priority task is placed second in the task list and operation of the high priority task is initiated. If the new task is low priority or if a high priority task is operating, the new task is placed in the task list in priority order to be operated as soon as possible.

Target Track Processing (TRKPRO) - (modified)

Since there is only one PEPE ensemble in this model, it is no longer necessary for TRKPRO to pass newly updated target track data to the Guidance Ensemble. Therefore, this function is eliminated and the routine which processed the data (TSVCO) has been dropped. It is still necessary for TRKPRO to coordinate dropping of target tracks with Intercept Planning Control but this function no longer requires inter-ensemble communication. The functions performed by Track Initiation (TRKINI) in the calibration model have been incorporated into TRKPRO, and TRKINI is no longer scheduled as a separate task.

Interceptor Track Processing (MITRK) - (unchanged)

Missile Control (GIDNC) - (unchanged)

Impact Point Prediction (IMPPT) - (modified)

In the Calibration Model, only one iteration of target prediction was performed during each operation of IMPPT to ensure that higher priority tasks did not miss deadlines for operation. In this model, IMPPT is a low priority, interruptable task. Therefore, it now completes threat discrimination for all eligible objects during one operation. Since there is only one PEPE ensemble in this model, it is no longer necessary to pass data on newly detected threatening objects to the Guidance Ensemble. IMPPT now performs any initialization necessary and the routine which previously performed this function (NSVCO) is no longer operated as a separate task.

Intercept Planning Control (INCTL) - (modified)

INCTL operated in the Guidance Ensemble in the Calibration Model; it is a low priority, interruptable task which is operated on a cyclic basis in this model. Since it is interruptable, the Kill Assessment function has been incorporated into INCTL. This is a time consuming tasks which operated in the Sequential Processor in the Calibration Model. This change required changing the time model for Kill Assessment from a sequential process to a parallel process.

Battlespace Planning (BTLSPC) - (modified)

BTLSPC is a time consuming process which operated in the Sequential Processor in the Calibration Model. It operates as a low priority, interruptable task in the PEPE Arithmetic System in this model. This change required a change in the time model to reflect the change from a sequential process to a parallel process and also the elimination of the passing of data between two facilities. The functions performed by BTLSPC are unchanged.

Intercept Plan Selection (INTSEL) - (modified)

In the Calibration Model, only one iteration of target prediction was performed during each operation of INTSEL. This required INTSEL to enable itself if fractricide could not be resolved for any threatening object under consideration. In this model, INTSEL is a low priority, interruptable task. Therefore, it now completes fractricide resolution for all objects under consideration during one operation.

3.2.4 Parallel Routines - PEPE Associative Output System

The PEPE Associativ Output System consists of a central Associative Output Control Unit (AOCU) and an Associative Output Unit (AOU) in each PEPE element. This system did not exist in the Calibration Model hardware; its functions were performed in the PEPE Arithmetic System. The AOCU is not interruptable; input messages cannot be processed until a task operating in the AOCU has completed operation.

Interrupt Handler (AOCU) - (new routine)

Upon receipt of a message from the Host, AOCU initiates operation of a task to be run in the PEPE Associative Output System. In this model, the only task to be run is Pulse Allocation.

Pulse Allocation (ALLOC) - (modified)

In the calibration model, interceptor track pulse requests were passed from the Guidance Ensemble and stored in an empty element in the Track Ensemble. It is not necessary to pass data between two ensembles in this model, but it is necessary to move interceptor track pulse requests to

elements which do not contain target track pulse requests so that pulse allocation can be performed as a parallel process. This function is performed in ALLOC. The routines which performed it in the Calibration Model (a portion of IPREX and IPRCO) are no longer scheduled as separate tasks. In this model, ALLOC enables Interceptor Track Processing, Target Track Processing, and Missile Control to operate in the PEPE Arithmetic System by sending a time event message to the Host. ALLOC itself is enabled by Missile Control as soon as it finishes operation.

3.2.5 Correlation Routines - PEPE Correlation System

The PEPE Correlation System consists of a Correlation Control Unit (CCU) and a Correlation Unit (CU) in each PEPE element. The CCU is not interruptable; input messages cannot be processed until a task operating in the CCU has completed operation. In the Calibration Model, all correlation routines were scheduled through the RIP by Radar Return Assimilation or Farm Return Assimilation and operated in order by priority. In this model instead of being scheduled, routines to process messages are operated as messages are received.

Interrupt Handler (CCU) - (new routine)

Upon receipt of a message from the RIC or from the Host, CCU initiates the operation of the requested task.

Surveillance Return Correlation (SURCO) - (Unchanged)
Track Initiate Return Correlation (TRICO) - (Unchanged)
Track Return Correlation (TRKCO) - (Unchanged)
Special Acquisition Return Correlation (SASCO) - (Unchanged)
Interceptor Return Correlation (INTCO) - (Unchanged)
Farm Return Correlation (FRMCO) - (Unchanged)

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TECH MEMO

a working paper

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PEPE FUNCTIONAL SIMULATION CALIBRATION MODEL

DETAILED TEST PLANS

[redacted]

A 3084 (1/72)

TABLE OF CONTENTS

1.0 INTRODUCTION

The PEPE simulation project is charged with the responsibility of developing a high level functional simulation model* of the PHSD tactical process operating on the MSI PEPE/CDC-7600/RIC equipment configuration. This model will be used to validate the design of the MSI PEPE.**

The approach being used for the development of the SVM model is to (1) construct a simulation model of the PHSD tactical process operation on the PEPE equipment configuration used for the PHSD demonstration back in September 1971; (2) calibrate (or tune) the model so that its performance is the same, within prescribed limits, as that experienced by PEPE IC design; and (3) then perturb or modify the simulation model to reflect the operation of the PHSD tactical process on the MSI configuration. The data obtained from the perturbed model will be used to determine the performance characteristics of the MSI PEPE (in a PHSD tactical situation).

The purpose of this document is to specify the tests that must be performed and the criteria that must be satisfied to calibrate the model of the PHSD tactical process operation on the PHSD equipment configuration.

1.1 RELATED DOCUMENTS

The detailed test plans and the results of the PEPE functional simulations are presented in a set of four related documents. These documents are:

PEPE Functional Simulation Calibration Model - Detailed Test Plans	TM-HU-048/500/00

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* This model is called the System Verification Model (SVM). The SVM has also been called the Version One Functional Simulator.

** The designation MSI PEPE may be ambiguous since both the two controller and three controller PEPEs have been called MSI at various times. At one time, the term MSI designated the speed of a two controller PEPE (i.e., .5 mip PEPE with IC-like design). In this document, the MSI designation will only be used to designate the three controller PEPE currently being designed. The terms "IC PEPE" or "PEPE IC DESIGN" will be used to designate the two controller PEPE. Also, the terms "IC PEPE" will not by itself designate any particular mip rating. Thus, the two controller .5 mip PEPE will be called the .5 mip IC PEPE.

PEPE Functional Simulation Calibration Model - Calibration Test Results	TM-HU-048/501/00
PEPE Functional Simulation System Verification Model - Detailed Test Plans	TM-HU-048/502/00
PEPE Functional Simulation System Verification Model - SVM Test Results	TM-HU-048/503/00

2.0 OBJECTIVE

The objective of the calibration test plan is to devise a set of tests and associated acceptance criteria that can be used to determine whether or not the simulation model is calibrated to the PHSD tactical process operating on the PEPE IC equipment configuration.

3.0 SCOPE OF THE CALIBRATION TESTS

The scope of the calibration tests must keep in mind the purpose or objective of the calibrated model. Since the calibrated model is going to be used as a baseline simulator which is subsequently modified (perturbed) to reflect the operation of the PHSD tactical process on the MSI PEPE, the scope of the test plan should include tests for functions whose implementation (on the MSI PEPE) is reasonable close to the implementation on the IC PEPE or for functions which directly affect system performance. For example, a function which was implemented as pure sequential in the IC system but which will be implemented as a parallel process in the MSI system and which does not affect system capability would be considered out of the scope of the calibration tests. The specific functions to be calibrated are identified in Section 5.

4.0 LIMITATIONS

In addition to the overall objective of the simulation project, the scope of the calibration model must take into consideration the realities of the real world. One of these realities is the availability of experimental data.

From the last of August until the plug (on the PEPE simulation system at Whippany, N.J.) was pulled in October 1971, a number of PHSD experiments were performed and a large amount of data was accumulated (None of which was required by contract). All of the summary data obtained from these experiments was indexed by the number of objects in early or precision track.

For several reasons, primarily the availability of manpower, computer time and calendar time, it was not possible to collect experimental data for all programs in the desired manner.

The experimentalists have, however, collected program execution data for some programs for certain conditions from the hard copy time lines. This is a laborious process which requires a painstaking reconstruction of the experimental situation. The time line printout only gives total execution time (scaled) and thus one cannot divide up this time into its various parallel and sequential components.

5.0 CALIBRATION MODEL

5.1 PHSD HARDWARE CONFIGURATION

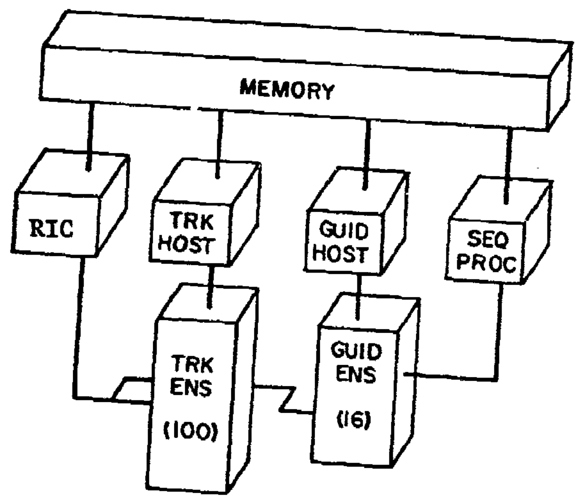
The hardware configuration for the PHSD system is shown in Figure 1. Basically, it is a four-processor multiprocessor configuration in which two of the sequential processors are augmented by a PEPE ensemble. All four sequential processors share a common memory. One of the sequential processors, the Radar Interface Computer (RIC), is a special purpose computer. The other three processors are identical. The RIC is rated at a nominal 6 mips. The other sequential computers will be rated at 2.4 or 6 mips depending on the particular test being performed. The sequential computers are assumed to have fast memory modules which are used to store PEPE programs and data. These memory modules are assumed to have a sustained transfer capability of one 32-bit word every 100 ns.

Two of the sequential processors have been augmented with PEPE ensembles. The PEPE ensembles are the two controller variety (ACU and CCU). The PEPE ensembles will be rated at either .5 mip or 1 mip depending on the test being performed.* Instruction and data are assumed to move between the Host and PEPE at a sustained rate of one 32-bit word every 100 ns. All format

* The PEPE mip ratings are somewhat confusing and should be clarified. The PEPE mip rating usually indicates the speed of the parallel arithmetic instructions. BTL rated the 16-element IC model at .25 mip. The published design goals for BTL's MSI PEPE was .5 mip or twice as fast as the IC model. BTL's MIS PEPE with a high speed multiply, was still referred to as a .5 mip computer (SDC called this version the MSI PEPE). The 1 mip PEPE is four times as fast as the IC Model.

In this document, the 1 mip PEPE is the one that is four times as fast as the IC Model. The .5 mip PEPE refers to BTL's MSI PEPE with a high speed multiply and therefore is acually faster than .5 mip PEPE.

conversion (e.g., conversion of Host integer to PEPE integer, conversion of PEPE logical to Host logical) is performed by hardware and is considered to be part of the interface unit between the Host and PEPE.



PHSD Hardware Configuration
Figure 1

5.2 PHSD SOFTWARE CONFIGURATION

The PHSD software configuration is shown in Figure 2. This figure shows the mapping of PHSD programs onto the data-processing resources. The radar-return assimilation, radar-order generation and the target-tracking-related correlation programs operate on the RIC. Radar pulse allocation, target track processing (Kalman filter), track initiate, and impact point prediction operate on the track PEPE-Host combination. Pulse allocation handles all radar pulses; i.e., search, target, and interceptor. Interceptor track processing, interceptor planning control, interceptor plan selection, guidance, etc., operate on the guidance PEPE-Host combination. Battlespace determination, kill assessment, farm-return assimilation, interceptor-return correlation, etc., operate on the third sequential processor.

5.3 CALIBRATION MODEL

The calibration tests have been divided into two classes; those tests which exercise PHSD tactical logic and are performance free, and performance related tests (See Section 6). The scope of the calibration model depends on the type of test being performed.

5.3.1 Calibration Model - BMD Effectiveness Tests

The scope of the calibration model for all BMD effectiveness tests is the same as that for the PHSD experiment; that is, the hardware model as shown in Figure 1 and the software system as shown in Figure 2.

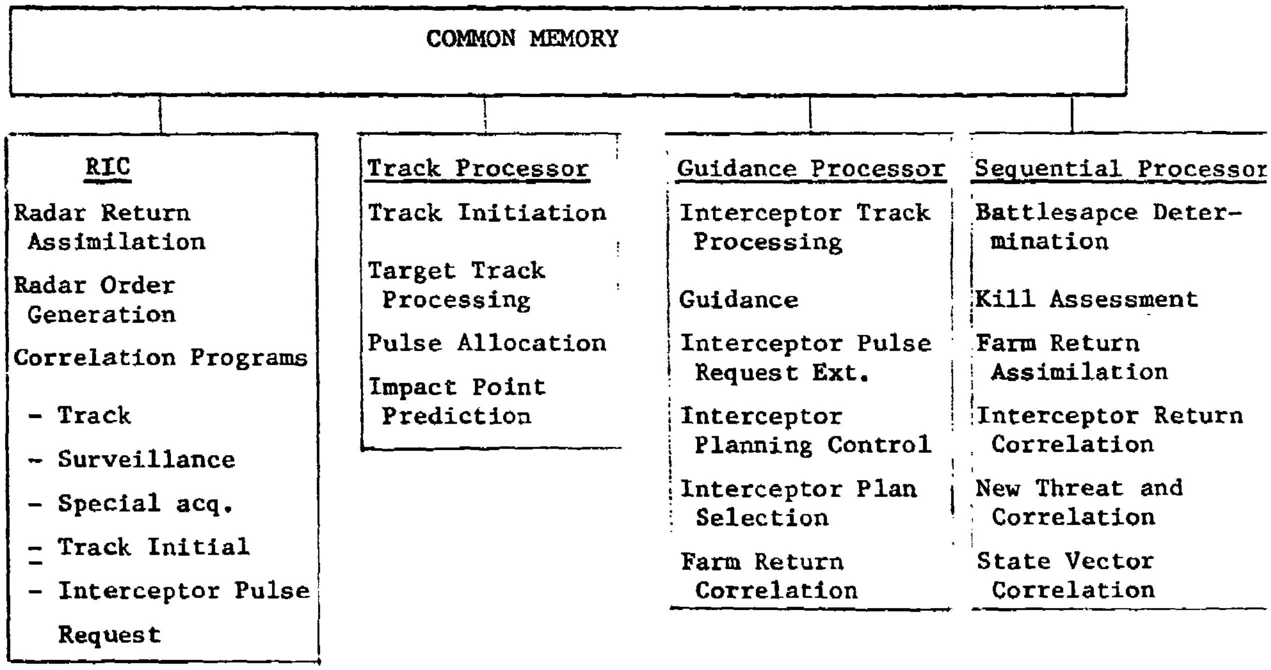


Figure 2. PHSD Software Configuration

5.3.2 Calibration Model - Performance Tests

The calibration model for the performance related calibration tests is a subset of the PHSD experimental model. The scope of the subset model is determined primarily by two factors: (1) the objectives of the PEPE simulation effort and (2) the availability of test data.

5.3.2.1 Programs Included in Calibration Model. All of the remaining PHSD programs will be incorporated into the calibration model. They include the following:

a. Track Ensemble

1. Target track processing (TRKPRO)
2. Track initiation (TRKINI)
3. Pulse Allocation (ALLOC)

b. Guidance Ensemble

1. Guidance (GIDNC)
2. Interceptor track processing (MITRK)
3. Intercept planning control INCTL)

A careful analysis of these programs shows that the program execution time for most programs is not a function of the number of objects in early or precision track, but some other variable. Table 5.1 shows the independent system variables for each of the programs included in the calibration model. The data collection (for calibration purposes) for those programs whose execution time is not a function of the number of objects in early or precision track is much more difficult because (1) no summary data is available and (2) the only data available is the total (scaled) execution time. One cannot separate this time into various components; e.g., sequential RTOS, sequential tactical, PINIT time, and parallel time. Thus, the calibration tests for these situations are necessarily more limited.

PROGRAM	INDEPENDENT SYSTEM VARIABLE
ALLOC	a. Number pulses processed.
	b. Number objects in early or precision task.
	c. Length of accumulation interval.
TRKINI	a. Track initation - 0 objects
	b. Track initation - 1 or more objects
TRKPRO	a. Number of objects in precision track.
INCTL	a. One pass through the program.
MITRK	a. Independent of all system parameters
GIDNC	a. No data.
	b. Element initialization.
	c. Performing guidance.
	d. b + c.

Independent System Variables for Calibration Programs

Table 5.1

5.3.2.2 Programs Not Included in Model. Using the above guidelines, the following programs will not be included in the calibration model for performance related calibration tests for the reasons cited:

a. Correlation Programs

The data gathering system for the PHSD experimental systems did not have any dynamic data gathering capability for the correlation programs. The estimated run time for each correlation program was a pre-calculated constant and was based on the most frequently executed path through each program. Calibration in this case would be trivial since one merely has to include a "delay x time units" statement in each correlation program. The PHSD correlation programs are:

Track correlation (TRKCO)
Special acquisition correlation (SASCO)
Surveillance return correlation (SURCO)
Interceptor pulse request correlation (IPRCO)
Track initiate correlation (TRICO)
Farm return correlation (FRMCO)
Interceptor return correlation (INTCO)
New state vector correlation (NSVCO)
Target state vector correlation (TSVC)

SURCO does, however, interrupt the ACU for the proper amount of time. This time will be accounted for in the calibration of the track processing parallel programs that are interrupted; e.g., pulse allocation.

b. Purely Sequential Programs

The programs executed in the Sequential Processor will not be included in the calibration model for two reasons; lack of data and the fact that the implementation design for these programs on the MSI PEPE (three controller) will be completely different than that used on the two controller IC PEPE. The sequential programs outside the scope of the calibration model are:

(1) Battlespace Determination (BTLSPC)

Battlespace determines the highest point on the trajectory predicted for a threatening object at which intercept is possible.

The execution time of the program depends on the geometry of the object since the program must iterate to determine the highest intercept point. Thus, the independent variable for Battlespace should include height of the object, number of iterations or some other geometric variable. Recording execution time as a function of the number of objects in early or precision track is clearly meaningless.

One time that might be measured is the average total execution time for a given mission; however, this would require a radar model with additional geometric capabilities.

(2) Kill Assessment (INQEST)

Kill Assessment determines whether or not an intercept against a radar attacker is successful. INQEST will not be included in the calibration model for several reasons; (1) there is very little data available on INQEST's program run time, (2) the available data is indexed by the wrong variable, (3) it is difficult for the two dimensional radar model to duplicate the three dimensional characteristics required for Kill Assessment and (4) the implementation on the MSI PEPE will be different.

(3) Farm Return Assimilation (FRMAS)

The Farm Return Assimilation program operates in the Sequential Processor and does not influence PEPE performance characteristics, and is therefore considered to be outside the scope of the calibration model.

c. RIC Programs

The RIC is a non-existent paper machine in PHSD. It was assumed to be "as fast as necessary" so that the RIC would never become the system bottleneck. Therefore, it is only necessary that the RIC programs; Radar Return Assimilation (PHAST) and Radar Order Generation (GENER), operate fast enough so that the RIC does not become the limiting factor in system performance.

Since PHSD system scheduling does not depend on the execution time of PHAST and GENER (provided they are reasonably small), no specific

calibration tests have been developed for the RIC programs. It is, however, suggested that these programs should be tuned so that their run time is reasonably close to that observed in PHSD.

d. Guidance Ensemble

One of the guidance ensemble programs, Interceptor Pulse Request Extraction (IPREX), functioned primarily as a communicator between the guidance and track ensembles and will not be included in a single ensemble configuration. Its other function of creating data set entries for communications with the missile farms will be incorporated into other programs in the MSI implementation.

Another guidance ensemble program, Intercept Plan Selection (INTSEL), will not be included in the calibration model for three reasons; (1) availability of data, (2) scope of the radar model, and (3) different MSI implementation.

The execution time for the Intercept Plan Selection Program depends on the number of program iterations. The number of iterations depends on the resolution of any detected fratricide condition. The liklihood of failing a fratricide test depends on the geometry of the incoming RV and the history of the engagements (i.e., locations of the planned intercept points on all previous intercept plans). Thus, the PHSD data collection programs should have recorded the INTSEL data as a function of the geometric situation.

Also, it will be very difficult to simulate three-dimensional fratricide test using a two-dimensional radar model.

Another reason for excluding the Intercept Plan Selection program from the calibration model is that its implementation on the MSI configuration will be different from that on the IC PEPE. In the IC system, the program had to be rescheduled when the fratricide test failed because of the non-interruptability requirements. In the MSI system, the program will simply iterate (at a lower priority) to completion.

e. Track Ensemble

One of the track ensemble programs, Impact Point Prediction (IMPPT), will not be included in the calibration model because of the avail-

ability of data. Impact point prediction performs two functions in PHSD, calculating the impact point of an object and deghosting. The independent variable for deghosting is the number of objects being deghosted. For impact point prediction, the independent variable is the maximum range of the objects involved in the current execution of the program.

6.0 CALIBRATION TESTS

Three types of calibration tests will be performed: BMD effectiveness tests, component calibration tests, and mission profile calibration tests.

The BMD effectiveness tests (Type I) check the tactical logic of the model. The objective of the Type I tests is to demonstrate that the calibration model properly exercises the PHSD engagement logic. The test is a comparison of the function history obtained from the simulator with that expected. If the results are within acceptable limits, the model passes the test.

The Type II tests, Component Calibration Tests, are designed to test the performance characteristics of the PHSD programs or other system attributes under carefully controlled situations. The amount of time required for ALLOC to allocate 8 radar pulses for a given equipment configuration is an example of a Type II test. Another example would be the amount of AU time required by TRKPRO on the .5 mip PEPE. All of the Type II tests have associated confidence limits which were obtained from a careful analysis of the PHSD data. Acceptance criteria have been specified for every Type II test.

The Mission Profile Calibration Tests, Type III tests, compare the results from a particular PHSD experimental run with that obtained from the simulator. The results will generally be presented (and compared) as a function of mission time. The acceptance criteria will be one of professional judgement rather than statistical analysis because of the availability of data (and the availability of theory) for generating reasonable acceptance criteria for this type of test.

6.1 TYPE I TESTS - BMD EFFECTIVENESS TESTS

The BMD effectiveness tests consist of a set of tests which exercise all significant branches of the PHSD engagement logic. Eight test scenarios have been designed. They range in complexity from a single non radar threat to a 17 object threat with radar attackers, non radar threats and non threatening. The Type I tests are similar to the GRC scenarios used for PHSD testing. The major difference being the fact that the calibration model uses a 2-dimensional radar and a simple atmospheric model.

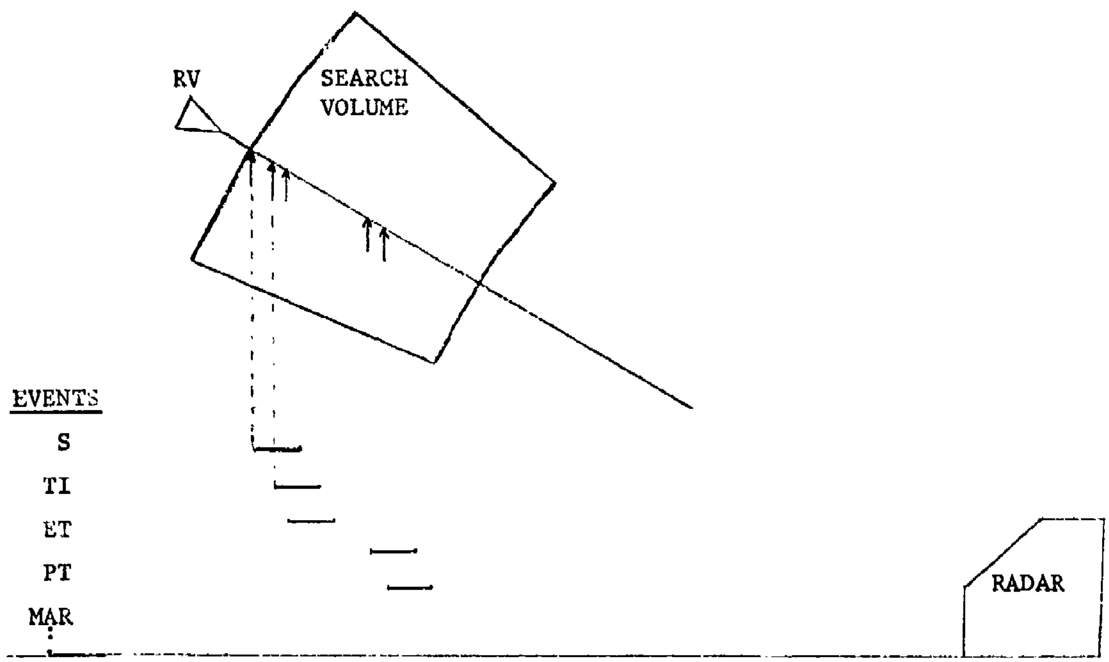
6.1.1 Acceptance Criterion

The acceptance criterion for the Type I tests is:the function history (obtained from the simulator) for each object in each test must be within the nominal specified functional history for each object where the functional history is the engagement time (expressed as seconds from RV launch) of the following events occur for each object:

1. Initial search hit
2. Track initiation
3. Early track
4. Precision track
5. MAR sent
6. LCS sent
7. Missile in track
8. Missile failure detected
9. Missile burst confirmed
10. Special acquisition
11. Target track dropped (final radar acquisition)

The expected time that each event should occur for a given object is a time interval (or window which depends on several factors; including the time that the object penetrates the search volume, the search sector scan rate, the engagement logic of the tactical process, the reach of the interceptor, the interceptor speed, etc). The function history for 5 events in the life of an object is depicted in figure 3. This figure is for explanatory purposes and is not drawn to scale. The figure shows a radar with its associated search volume and an RV about to enter the search volume. The scale on the bottom is engagement time measured in seconds from RV launch. The solid line through the search volume represents the RV trajectory. The arrows touching the trajectory show the earliest time that each of the five events, identified below the figure, can occur for this particular RV. For example, the earliest object

detection time by a search pulse (return) is the moment the RV enters the search volume. This would occur if the sequencing of the search raster was such that a search pulse was scheduled for the RV entry position the moment it entered the search volume. The latest time that the object can be detected depends on the search sector scan rate. If the search raster sweeps the sector once every second, then the latest time that the object would be detected, is one second after entering the search sector. (This assumes that the object is detected when it is illuminated by a radar pulse, which is assumed to always occur in the following tests). This earliest-latest time interval (or window) is represented by the solid line associated with each event.



SECONDS FROM LAUNCH

FIGURE 3

Track initiation occurs as soon as a search/verify pair are received which under the PHSD engagement logic is 23 ms after the first positive search return. Thus the earliest that track initiation can occur is 23 ms after the object enters the search volume. The size of the window is again dependent on the search raster scan rate. The remaining windows are determined in a similar fashion.

6.1.2 Type I Tests - General Description

A general description of the Type I tests follows. A summary of the BMD effectiveness tests with a list of the PHSD functions exercised by each test is presented in Table 6.1

Test 1 (Reference GRC Scenario 11)

The attack plan for test 1 consists of a single RV being classified as a non-radar threat (NRT). The objective of the test is to show that the simulator is able to detect and track an object, and plan and execute its intercept. No missile failures are allowed in test 1. All tracking functions, with the exception of Special Acquisition and Track-While-Scan, are exercised. All interceptor functions, except kill assessment and post-LCS failure replacements, are exercised.

Test 2 (Reference GRC Scenario 11)

Same as test 1 except that a pre-launch missile failure occurs on the first missile. The objective of the test is to show that the missile is replaced and the interception is completed.

Test 3 (Reference GRC Scenario 11)

Same as test 1 except that a post-launch missile failure occurs. A second missile is not replanned since the RV is classified as a non-radar threat. Instead the object is dropped from track after the failure is detected.

Test 4 (Reference GRC Scenario 11)

The attack plan for this test is similar to that of test 1 except the RV is classified as a radar threat (rather than a non-radar threat). A post-launch missile failure occurs during this test. The objective of this test is to show that (after detection of the first missile failure) a second intercept is planned and successfully implemented. All functions except Special Acquisition and Track-While-Scan are exercised during this test.

Test 5 (Reference GRC Scenario 12)

The attack plan for this test consists of 10 RV's, some being classified as non-radar threats and some as radar threats. No missile failures

CALIBRA..ON MODEL

BMD EFFECTIVENESS TESTS

TEST NO.	GRC SC#	NO. OBJECTS	THREAT STATUS	MISSILE FAILURE Y/N	MISSILE FAILURE TYPE	FUNCTIONS TESTED: Radar Ret. Assimilation	Surveillance Proc. Ex. TWS	TWS	Special Acq.	Target Trk. Proc.	Int. Plan CTL ex. KILLA, post L.F.R.	Kill Assmnt.	Post LCS Replacement	Battle Space	Inter. Plan Selection	Farm Comm.	Missile CTL	Inter. Trk. Processing	Pulse Alloc.	Radar Order Gen.
1	11	1	NRT	N		X	X			X	X			X	X	X	X	X	X	X
2	11	1	NRT	Y	Pre-Launch	X	X			X	X			X	X	X	X	X	X	X
3	11	1	NRT	Y	Post-Launch	X	X			X	X			X	X	X	X	X	X	X
4	11	1	RT	Y	Post-Launch	X	X			X	X	X	X	X	X	X	X	X	X	X
5	12	10	RT,NRT	N		X	X		X	X	X	X		X	X	X	X	X	X	X
6	12	10	RT,NRT	Y	Post-Launch	X	X		X	X	X	X	X	X	X	X	X	X	X	X
7	13	17	RT,NRT,NT	N		X	X	X	X	X	X	X		X	X	X	X	X	X	X
8	13	17	RT,NRT,NT	Y	Post-Launch	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 6.1

occur during this test. The radar cross section (RCS) of two of the objects go to zero for 1-2 seconds thereby exercising the Special Acquisition branch of the PHSD logic. The objective of this test is to show that multiple objects can be detected, tracked and intercepted. The Track-While-Scan (TWS) and post-LCS (Launch Command Sequence) replacement functions are not exercised during this test.

Test 6 (Reference GRC Scenario 12)

This test is the same as test 5 except that a post-launch missile failure occurs on a radar attacker. A second shot should be replanned and successfully executed.

Test 7 (Reference GRC Scenario 13)

The threat for test 7 consists of 12 RV's, one tank and four tank fragments. The tank and four tank fragments will be classified as non-radar threats. One of the RV's is also classified as a non-radar threat. Therefore, six objects will exercise the Track-While-Scan (TWS) branch of the PHSD logic. The Special Acquisition logic will also be exercised, since the radar cross section (RCS) of two of the RV's will go to zero for about 2 seconds. No missile failures will occur during this test.

Test 8 (Reference GRC Scenario 13)

This test is the same as 7 except that post-launch missile failures occur. Two failures occur on missiles assigned to radar threats and one on a missile assigned to a non-radar threat. A second interception should be planned and executed against the radar attackers. The non-radar threat should be dropped after detection of the failure. This test exercises all PHSD functions.

6.1.3 Equipemnt Configuration

The equipment configuration required for the Type I tests is the full PHSD equipment configuration as shown in Figure 1 of this document. Since the Type I tests are performance (i.e., run time) independent, no specific hardware performance characteristics have been specified. This also applies to the radar block size. The experiments should use parameters that are convenient for the tests.

6.1.4 Search Volume

The search volume associated with the Calibration Model is assumed to consist of three search sectors and that the scan rate for each sector can be specified by the test planner. The scan rates chosen for the BMD effectiveness tests are as follows:

Search Sector	Time per scan
1	3.85 sec.
2	2.2 sec.
3	1.65 sec.

It should also be noted that all function history calculations are based on the assumption that the minimum and maximum ranges can be specified for each search sector.

6.1.5 Tracking Rate

All objects are assumed to be tracked at 20 Hertz.

6.1.6 Test Sequence

There are no specific requirements for sequencing the Type I tests. Test 8, the most complex test, exercises all required PHSD logic branches. Therefore, satisfactory completion of test 8 obviates the other seven tests.

6.1.7 Type I Tests - Detailed Test Plan

A detailed description of the Type I test plan for the Calibration Model follows. The acceptance criteria (i.e., nominal functional history) is included for each test.

6.1.7.1 Test 1 (Reference GRC Scenario 11). The attached plan for test 1 consists of a single RV entering search sector 3 at beam position 300. The RV is classified as a non-radar threat (NRT). The RV enters the volume at 2985 seconds and its range at entry is 92 km. The RV's speed is 7100m/s throughout the exercise.

The minimum and maximum search ranges for search sector 3 are:

Minimum range	66 km.
Maximum range	92 km.

No missile failures occured during this test. The interceptor speed is 2360m/s.

The nominal function history for test 1 is presented in Table 6.2.

ENGAGEMENT TIME (Sec)	FUNCTION
2985.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2995.54 - 2996.35	Missile burst confirmed
2995.54 - 2996.90	Target track dropped

Function History
Table 6.2

6.1.7.2 Test 2 (Reference GRC Scenario 11). Same as test 1 except that a prelaunch missile failure occurs on the first missile assigned to the RV. A second missile is assigned and the mission proceeds without any further failures.

The functional history for test 2 is presented in Table 6.3. Note that it is the same as that for test 1.

ENGAGEMENT TIME (Sec)	FUNCTION
2985.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2995.54 - 2996.35	Missile burst confirmed
2995.54 - 2996.90	Target track dropped

Function History

Table 6.3

6.1.7.3 Test 3 (Reference GRC Scenario 11). This test is basically the same as test 1. The only difference being that a failure occurs in the first interceptor assigned to the target at 2.75 seconds after launch. A second interceptor is not assigned to this target since it is classified as a non-radar threat (NRT). The object should be dropped from track after the failure has been detected.

The nominal function history for test 3 is presented in Table 6.4.

ENGAGEMENT TIME (Sec)	FUNCTION
2985.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2990.92 - 2994.32	Missile failure detected
2990.92 - 2994.87	Target track dropped

Function History

6.1.7.4 Test 4 (Reference GRC Scenario 11). The attack plan for this test consists of a single RV entering search sector 3 at beam position 300. The RV is classified as a radar threat (RT). The first interceptor assigned to this target has a post launch failure which occurs at 2.75 seconds after launch. A second interception is to be planned and executed.

The object enters the search volume at 2981 seconds. Its range at entry is 120.4 km. The speed of the target is 7100 m/s.

The speed sector range gates for this test are:

Minimum range	94 km
Maximum range	121 km.

The interceptor speed is 2360 m/s.

The nominal function history for test 4 is presented in Table 6.5.

ENGAGEMENT TIME (Sec)	FUNCTION
2981.00 - 2982.65	Initial search/verify hits
2981.02 - 2982.67	Track initiation
2981.12 - 2982.77	Early track
2983.52 - 2985.17	Precision track
2983.52 - 2986.27	MAR sent
2983.67 - 2986.52	LCS sent
2985.72 - 2989.57	Missile track acquired
2986.92 - 2990.32	Missile failure detected
2986.92 - 2990.92	MAR sent
2987.07 - 2992.12	LCS sent
2989.12 - 2994.32	Missile track acquired
2995.32 - 2996.75	Missile brust confirmed
2995.32 - 2997.30	Target track dropped

Function History

Table 6.5

6.1.7.5 Test 5 (Reference GRC Scenario 12). The attack plan for test 5 consists of 10 RV's entering search sectors 1 and 3. Six of the RV's are classified as radar threats (RT) and four as non-radar threats (NRT). The radar cross section (RCS) on two of the objects go to zero for about 2 seconds; the RCS for objects 3 and 4 is zero during the time intervals 2973.50 - 2975.40 seconds and 2981.00 - 2983.00 seconds respectively. Both of these targets should cause the Special Acquisition logic to be exercised.

The minimum and maximum search ranges for search sectors 1 and 3 for this test are:

Search sector	Search range (km.)	
	Minimum	Maximum
1	105	135
3	66	98

All targets have the same speed - 7100 m/s.

All interceptors have the same speed - 2360 m/s.

No interceptor failures occur during this test.

The threat status, search sector entered, time of entry into search volume, beam position at entry and range at entry for each object in the test follows:

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	TIME OF ENTRY	BEAM POSITION	RANGE AT ENTRY
1	RT	1	2967	50	135
2	RT	1	2971	75	135
3	RT	1	2967	100	135
4	RT	1	2971	125	135
5	RT	1	2967	150	135
6	RT	1	2971	175	135
7	NRT	3	2974	300	98
8	NRT	3	2974	400	98
9	NRT	1	2977	300	135
10	NRT	1	2977	350	135

The anticipated function history for each object is presented in Table 6.6.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped
	--continued--

Function History

Table 6.6

Table 6.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 2	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 3	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.65 - 2973.75	Special acquisition
2975.40 - 2975.55	Precision track or track initiate
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped.

-- continued --

Table 6.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 4	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2981.15 - 2981.25	Special acquisition
2983.00 - 2983.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 5	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

-- continued --

Table 6.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 7	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped
Object No. 8	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped

-- continued --

Table 6.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped
Object No. 10	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped

6.1.7.6 Test 6 (Reference GRC Scenario 12). This test is basically the same as test 5 except for a post launch failure on three interceptors. The targets enter exactly the same way as in test 5; the same entry point, same ranges and the same times. The target threat status is the same as in test 5. The targets enter at the same speed.

The radar cross sections (RCS) for objects 3 and 4 go to zero for the same period of time.

The only difference is that in test 6 a post launch missile failure occurs in the first missile assigned to objects 1, 2, and 7. The missile failure

time for each object is:

Object	Failure after Launch
1	3.5 sec.
2	3.0 sec.
7	2.75 sec.

A second interception should be planned and executed against objects 1 and 2 since they are radar attackers. Object 7 should be dropped from track after the missile failure has been detected.

The interceptor speeds for test 6 are the same as those for test 5.

The function history for each object in test 6 is presented in Table 6.7.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.67 - 2979.95	Missile failure detected
2973.67 - 2980.55	MAR sent
2973.82 - 2981.75	LCS sent
2975.87 - 2983.95	Missile track acquired
2983.12 - 2985.20	Missile burst confirmed
2983.12 - 2985.75	Target track dropped

-- continued --

Function History

Table 6.7

Table 6.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 2	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2977.17 - 2983.45	Missile failure detected
2977.17 - 2984.05	MAR sent
2977.32 - 2985.25	LCS sent
2979.37 - 2987.45	Missile track acquired
2986.99 - 2989.18	Missile burst confirmed
2986.99 - 2989.73	Target track dropped
Object No. 3	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.65 - 2973.75	Special acquisition
2975.40 - 2975.55	Precision track or track initiate
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

-- continued --

Table 6.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 4	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2981.15 - 2981.25	Special acquisition
2983.00 - 2983.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 5	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

-- continued --

Table 6.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 7	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2979.82 - 2984.27	Missile failure detected
2979.82 - 2984.82	Target track dropped
Object No. 8	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped

-- continued --

Table 6.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped
Object No. 10	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped

6.1.7.7 Test 7 (Reference GRC Scenario 13). The attack plan for test 7 consists of 17 objects; 3 radar threats (RT), 8 non-radar threats (NRT), and 6 non-threatening objects (NT). The objects enter all three sectors of the search volume. The entry characteristics of each object follows:

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	ENTRY TIME	BEAM POSITION	ENTRY RANGE
1	NRT	3	2982	100	98
2	RT	1	2969	50	135
3	NRT	2	2974	20	118
4	NRT	2	2974	40	115

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	ENTRY TIME	BEAM POSITION	ENTRY RANGE
5	NRT	1	2970	200	135
6	NT	2	2974	60	125
7	NT	2	2973	80	125
8	NT	2	2975	100	125
9	RT	1	2971	250	135
10	NRT	2	2973	120	120
11	RT	2	2973	140	119
12	NRT	2	2974	160	123
13	NT	2	2978	180	115
14	NT	3	2975	200	108
15	NRT	3	2974	300	104
16	NT	2	2973	200	125
17	NRT	2	2975	220	120

The entry speed for all objects is the same - 7100 m/s.

The minimum and maximum ranges for each search sector for test 7 are:

Search Sector	Range (km) Minimum	Maximum
1	105	135
2	85	125
3	75	110

Notice that during this test, the objects do not always enter at the maximum range of the search sector. The reason for doing this is to control the amount of time that each object spends in the search volume.

The radar cross section (RCS) for object 9 is zero during the interval 2980.00 - 2982.00 seconds. This object should exercise the Special Acquisition path of the tactical logic.

Objects 6, 7, 8, 13, 14 and 16 are non-threatening objects and should be placed in Track While Scan. They should be dropped from track after leaving the search volume.

No interceptor failures occur in this test. All interceptors fly at 2360 m/s.

The function history for each object is presented in Table 6.8.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2982.00 - 2983.65	Initial search/verify hits
2982.02 - 2983.67	Track initiation
2982.12 - 2983.77	Early track
2984.52 - 2986.17	Precision track
2984.52 - 2987.27	MAR sent
2984.67 - 2988.47	LCS sent
2986.72 - 2990.67	Missile track acquired
2993.17 - 2994.24	Missile burst confirmed
2993.17 - 2994.79	Target track dropped
Object No. 2	
2969.00 - 2972.58	Initial search/verify hits
2969.02 - 2972.60	Track initiation
2969.12 - 2972.70	Early track
2971.52 - 2975.10	Precision track
2971.52 - 2976.20	MAR sent
2971.67 - 2977.40	LCS sent
2973.72 - 2979.60	Missile track acquired
2984.08 - 2985.62	Missile burst confirmed
2984.08 - 2986.17	Target track dropped
	--continued--

Function History

Table 6.8

Table 6.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 3	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.12	Missile track acquired
2986.23 - 2988.92	Missile burst confirmed
2986.23 - 2989.47	Target track dropped
Object No. 4	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2987.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.97 - 2988.61	Missile burst confirmed
2986.97 - 2989.16	Target track dropped
Object No. 5	
2970.00 - 2973.58	Initial search/verify hits
2970.02 - 2973.60	Track initiation
2970.12 - 2973.70	Early track
2972.52 - 2976.10	Precision track
2972.52 - 2977.20	MAR sent
2972.67 - 2978.40	LCS sent
2974.72 - 2980.60	Missile track acquired
2985.08 - 2986.62	Missile burst confirmed
2985.08 - 2987.17	Target track dropped

-- continued --

Table 6.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Track while scan
2979.63 - 2981.83	Drop track while scan
Object No. 7	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 8	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Track while scan
2980.63 - 2982.83	Drop track while scan
Object No. 9	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2980.15 - 2980.25	Special acquisition
2982.00 - 2982.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped

-- continued --

Table 6.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 10	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.60 - 2988.18	Missile burst confirmed
2986.60 - 2988.68	Target track dropped
Object No. 11	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.12	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.39 - 2988.03	Missile burst confirmed
2986.39 - 2988.58	Target track dropped
Object No. 12	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.12	Missile track acquired
2986.55 - 2989.45	Missile burst confirmed
2986.55 - 2990.00	Target track dropped

-- continued --

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2982.00 - 2983.65	Initial search/verify hits
2982.02 - 2983.67	Track initiation
2982.12 - 2983.77	Early track
2984.52 - 2986.17	Precision track
2984.52 - 2987.27	MAR sent
2984.67 - 2988.47	LCS sent
2986.72 - 2990.67	Missile track acquired
2993.17 - 2994.24	Missile burst confirmed
2993.17 - 2994.79	Target track dropped
Object No. 2	
2969.00 - 2972.58	Initial search/verify hits
2969.02 - 2972.60	Track initiation
2969.12 - 2972.70	Early track
2971.52 - 2975.10	Precision track
2971.52 - 2976.20	MAR sent
2971.67 - 2977.40	LCS sent
2973.72 - 2979.60	Missile track acquired
2974.92 - 2981.20	Missile failure detected
2974.92 - 2981.80	MAR sent
2975.07 - 2983.00	LCS sent
2977.12 - 2985.20	Missile in track
2984.93 - 2987.01	Missile burst confirmed
2984.93 - 2987.56	Target track dropped

-- continued --

Function History

Table 6.9

Table 6.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 3	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.23 - 2988.92	Missile burst confirmed
2986.23 - 2989.47	Target track dropped
Object No. 4	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.97 - 2988.61	Missile burst confirmed
2986.97 - 2989.16	Target track dropped
Object No. 5	
2970.00 - 2973.58	Initial search/verify hits
2970.02 - 2973.60	Track initiation
2970.12 - 2973.70	Early track
2972.52 - 2976.10	Precision track
2972.52 - 2977.20	MAR sent
2972.67 - 2978.40	LCS sent
2974.72 - 2980.60	Missile track acquired
2975.92 - 2982.20	Missile failure detected
2975.92 - 2982.75	Target track dropped

-- continued --

Table 6.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Track while scan
2979.63 - 2981.83	Drop track while scan
Object No. 7	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 8	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Track while scan
2980.63 - 2982.83	Drop track while scan
Object No. 9	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2976.92 - 2983.20	Missile failure detected
2976.92 - 2983.80	MAR sent
2977.07 - 2985.00	LCS sent
2979.12 - 2987.20	Missile in track

-- continued --

Table 6.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9 (cont'd.)	
2980.15 - 2980.25	Special acquisition
2982.00 - 2982.25	Precision track or track initiation
2986.93 - 2989.01	Missile burst confirmed
2986.93 - 2989.56	Target track dropped
Object No. 10	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.60 - 2988.18	Missile burst confirmed
2986.60 - 2988.68	Target track dropped
Object No. 11	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.39 - 2988.03	Missile burst confirmed
2986.39 - 2988.58	Target track dropped

-- continued --

Table 6.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 13	
2978.00 - 2980.20	Initial search/verify hits
2978.02 - 2980.22	Track initiation
2978.12 - 2980.32	Early track
2980.52 - 2982.72	Track while scan
2982.23 - 2984.43	Drop track while scan
Object No. 14	
2975.00 - 2976.65	Initial search/verify hits
2975.02 - 2976.67	Track initiation
2975.12 - 2976.77	Early track
2977.52 - 2979.17	Track while scan
2980.65 - 2982.30	Drop track while scan
Object No. 15	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2976.72 - 2982.67	Missile track acquired
2985.81 - 2986.86	Missile burst confirmed
2985.81 - 2987.41	Target track dropped
Object No. 16	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.63	Drop track while scan

-- continued --

Table 6.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 17	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Precision track
2977.52 - 2980.82	MAR sent
2977.67 - 2982.02	LCS sent
2979.72 - 2984.22	Missile track acquired
2987.55 - 2990.13	Missile burst confirmed
2987.55 - 2990.63	Target track dropped

6.1.7.8 Test 8 (Reference GRC Scenario 13). This test is exactly the same as test 7 except that three interceptors fail in flight. Two of the failures are against radar attackers and one against a non-radar threat. A second interception should be planned and executed against the radar attackers. The NRT object should be dropped from track as soon as the failure is detected.

The failures are associated with interceptors assigned to objects 2, 5, and 9. All failures occur at 2.75 seconds after launch.

Note: If everything works as expected, these failures should occur in the first three missiles launched with the first interceptor assigned to object 2, the second to object 5 and the third to object 9.

The RCS on object 9 goes to zero for the same period of time as in test 7.

The expected function history for each object in test 8 is presented in Table 6.9.

Table 6.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 12	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2977.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.55 - 2989.45	Missile burst confirmed
2986.55 - 2990.00	Target track dropped
Object No. 13	
2978.00 - 2980.20	Initial search/verify hits
2978.02 - 2980.22	Track initiation
2978.12 - 2980.32	Early track
2980.52 - 2982.72	Track while scan
2982.23 - 2984.43	Drop track while scan
Object No. 14	
2975.00 - 2976.65	Initial search/verify hits
2975.02 - 2976.67	Track initiation
2975.12 - 2976.77	Early track
2977.52 - 2979.17	Track while scan
2980.65 - 2982.30	Drop track while scan

-- continued --

Table 6.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 15	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.81 - 2986.86	Missile burst confirmed
2985.81 - 2987.41	Target track dropped
Object No. 16	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 17	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Precision track
2977.52 - 2980.82	MAR sent
2977.67 - 2982.02	LCS sent
2979.72 - 2984.22	Missile track acquired
2987.55 - 2990.13	Missile burst confirmed
2987.55 - 2990.63	Target track dropped

6.2 TYPE II TESTS - COMPONENT CALIBRATION TESTS

This section presents a detailed description of the Component Calibration or Type II tests. In general, the Type II tests will be performed on those components (usually programs) of the PHSD system for which there is sufficient data available for the calculation of confidence limits. Also, the Type II tests are performed under carefully controlled conditions (e.g., the amount of AU time as a function of the number of pulses processed) rather than a more gross test (e.g., the average execution time of a program for an entire mission) since it is very difficult to duplicate all aspects of a mission. Type II calibration tests will be performed on the following components of the PHSD system:

Pulse Allocation (ALLOC)

- o Parallel (AU) time
- o Total run time

Track initiation (TRKINI)

- o Total run time

Target track processing (TRKPRO)

- o Parallel (AU) time

Interceptor track processing (MITRK)

- o Parallel (AU) time
- o Total run time

Guidance (GINDC)

- o Total run time

Interceptor planning control (INCTL)

- o Total run time

PEPE accumulation interval

6.2.1 Test 9 - Pulse Allocation (ALLOC)

Two types of tests have been specified for the Pulse Allocation program. The first test is a test of PEPE parallel (AU) time. The second is a test of the total parallel and sequential run time of ALLOC. (See Appendix B for the derivation of the calibration limits).

6.2.1.1 Test 9.1 - Parallel (AU) Time - 1 mip PEPE. This test is to determine whether or not the average parallel (AU) time per millisecond (ms) of accumulation interval as a function of the number of objects in early or precision track is within prescribed limits.

6.2.1.1.1 Test Conditions. The conditions for this test are:

Tracking rate - 20 Hz.

PEPE speed - 1 mip

Threat - Various threats can be used; e.g., "in-house simulator", GRC scenarios 13, 14, 15.

Radar block size - 2

Host scale factor - 0.10

6.2.1.1.2 Limitation. This test is only valid for 30 or fewer objects in early or precision track.

6.2.1.1.3 Acceptance Criteria. The following method should be used to evaluate the results obtained from the simulator:

1. Select those values of n (the number of objects in early or precision track) for which the number of execution of ALLOC is greater than or equal to 5.

2. For each value of n selected in 1 above, calculate the average AU time (μ).

3. For each value of n selected in 1, calculate the average accumulation interval (ms).

4. Divide the average AU time by the average accumulation interval.

5. Compare the results with the calibration limits specified below or with the values contained in Table 6.10 which has been included for convenience. The values in Table 6.10 are rounded to the nearest microsecond and in case of doubt, the values obtained from the formulas override those in the table.

6. The results are considered to be acceptable if at least 95% of the results fall within the 95% calibration limits.

6.2.1.1.4 Calibration Limits. The upper and lower 95% calibration limits are:

$$t_{AU,\overline{95}} = 63.14 + 1.169\ n$$

$$t_{AU,\underline{95}} = 53.38 + 1.169\ n$$

where: $t_{AU,\overline{95}}$ is the upper 95% calibration limit (μ)

$t_{AU,\underline{95}}$ is the lower 95% calibration limit (μ)

n is the number of objects in early or precision track

The expected average AU time (μ) per ms of accumulation interval for both cases is:

$$t_{AU} = 58.255 + 1.169\ n$$

PULSE ALLOCATION - AVERAGE AU TIME (μ) PER MSEC
OF ACCUMULATION INTERVAL FOR 1 MIP PEPE

OBJECTS IN TRACK	95% CONF. LIMITS (nearest μ)
0	53 - 63
1	54 - 64
2	56 - 65
3	57 - 67
4	58 - 68
5	59 - 69
6	60 - 70
7	62 - 71
8	63 - 72
9	64 - 74
10	65 - 75
11	66 - 76
12	67 - 77
13	69 - 78
14	70 - 80
15	71 - 81
16	72 - 82
17	72 - 83
18	73 - 84
19	76 - 85
20	77 - 87
21	78 - 88
22	79 - 89
23	80 - 90
24	81 - 91
25	83 - 92
26	84 - 94
27	85 - 95
28	86 - 96
29	87 - 97
30	88 - 98

Table 6.10

6.2.1.2 Test 9.2 - Parallel (AU) Time - .5 mip PEPE. Same test conditions as for test 9.1 except that the 1 mip PEPE has been replaced by a .5 mip PEPE.

The evaluation of the test results is the same as for Test 9.1 except that the average AU time should be divided by 1.7 before applying the calibration limit tests.

The acceptance criteria is the same, namely that at least 95% of the results must fall within the 95% calibration limit.

6.2.1.3 Test 9.3 - Total Run Time. This test is to determine whether or not the average total (scaled) run time for Pulse Allocation as a function of the number of pulses processed is within prescribed limits. Analysis of the PHSD data has shown that the average total run time for the Pulse Allocation program is a linear function of the number of pulses processed.

6.2.1.3.1 Test Condition. This test will consist of one test under the following conditions:

Tracking rate - 20 Hz.
PEPE speed - 1 mip
Host scale factor - 0.1
Radar block size - 2 ms
Threat - " In-house simulator"

6.2.1.3.2 Limitation. This test is only valid for the number of pulses processed (not including search pulses) is less than or equal to 25.

6.2.1.3.3 Acceptance Criteria. The following method should be used to evaluate the results obtained from the simulator:

1. Select those values of x (the number of pulses processed; not including search pulses) for which the number of executions of ALLOC is greater than or equal to 5.

2. For each value of x selected in 1 above, calculate ALLOC's average total processing time.

3. Compare the results with the calibration limits specified below.

4. The test results are considered acceptable if at least 95% of the results fall within the 95% calibration limits.

6.2.1.3.4 <u>Confidence Limits.</u> The upper and lower 95% calibration limits for the average total run time (ms) for ALLOC are:

$$t_{ALLOC,\overline{95}} = 5.87 + 0.1214x$$

$$t_{ALLOC,\underline{95}} = 5.11 + 0.1214x$$

6.2.2 <u>Test 10 - Track Initiation (TRKINI)</u>

One test has been specified for the Track Initial program (TRKINI). That test is quite simply a test of TRKINI's average total run time under two conditions, (1) track initiation zero objects; (2) track initiation 1 or more objects.

6.2.2.1 <u>Test Condition.</u> The TRKINI test will consist of one test under the following conditions:

Tracking rate - 20 Hz
PEPE speed - 1 mip
Host scale factor - 0.1
Radar block size - 2 ms
Threat - "In-house simulator"

6.2.2.2 <u>Acceptance Criteria.</u> The following method should be used to evaluate the results obtained from the simulator:

1. Calculate TRKINI's average total run time (μ) under two conditions:
   o TI 0 objects
   o TI $\geq$1 object
   The average run time should consist of at least 5 iterations of the program under both conditions.

2. The Track Initiate component of the calibration model is considered to be acceptable if both values calculated in 1 above are within the following calibration limits:
   o 0 objects 106.3 - 144.3μ
   o $\geq$1 object 203.1 - 244.3μ

6.2.3 Test 11 - Target Track Processing (TRKPRO)

One test has been specified for the Target Track Processing program (TRKPRO). The test is for the average parallel (AU) time as a function of the number of objects in early or precision track.

Analysis of the PHSD data has shown that the parallel time for TRKPRO is a linear function of the number of objects in early or precision track. (See Appendix C). This test is to determine whether or not the average parallel time obtained from the calibration model falls within prescribed calibration limits. Two AU tests will be performed; one for the 1 mip PEPE and the other for the .5 mip PEPE.

6.2.3.1 Test 11.1 - Parallel (AU) Time - 1 mip PEPE

6.2.3.1.1 Test Conditions. The test conditions for both the AU part of the TRKPRO test are as follows:

Tracking rate - 20 Hz
PEPE speed - 1 mip
Host scale factor - 0.1
Radar block size - 2 ms
Threat - "In-house simulator"

6.2.3.1.2 Limitation. The calibration limits for this test are only valid for less than or equal to 30 objects in early or precision track.

6.2.3.1.3 Acceptance Criteria. The following method should be used to evaluate the results obtained from the simulator:

1. Select those values of n (the number of objects in early or precision track) for which the number of executions of TRKPRO is greater than or equal to 5.
2. For each value of n selected above, calculate TRKPRO's average parallel time.
3. Compare the results with the calibration limits specified above.
4. The test results are considered acceptable if at least 95% of the results fall within the 95% calibration limits.

6.2.3.1.4 Calibration Limits. The upper and lower 95% calibration limits for TRKPRO's AU time for a 1 mip PEPE are:

$$t_{TRKPRO,\overline{95}} = 3.621 + 0.00224n$$

$$t_{TRKPRO,\underline{95}} = 3.534 + 0.00224n$$

where: $t_{TRKPRO,\overline{95}}$ is the upper 95% calibration limit for TRKPRO's AU time (ms)

$t_{TRKPRO,\underline{95}}$ is the lower 95% calibration limit for TRKPRO's AU time (ms)

n is the number of objects in early or precision track ($n \leq 30$)

6.2.3.2 Test 11.2 - Parallel (AU) Time - .5 mip PEPE. The test for the .5 mip PEPE is the same as that specified for the 1 mip PEPE except that .5 replaces the 1 in the test conditions and the calibration limits change. The calibration limits for the .5 mip PEPE are:

95% calibration limits

$$t_{TRKPRO,\overline{95}} = 4.526 + 0.0028n$$

$$t_{TRKPRO,\underline{95}} = 4.417 + 0.0028n$$

where all terms are as defined before.

6.2.4 Test 12 - Interceptor Track Processing (MITRK)

Three tests have been specified for the Interceptor Track Processing program (MITRK); one for the average total run time, one for the average parallel time for a 1 mip PEPE and one for the average parallel time for a .5 mip PEPE.

6.2.4.1 Test 12.1 - Total Run Time

6.2.4.1.1 Test Conditions. The test conditions for the total run time test for MITRK are:

Tracking rate - 20 Hz

PEPE speed - 1 mip

Host scale factor - 0.1

Radar block size - 2 ms

Threat - "In-house simulator"

6.2.4.1.2 Acceptance Criteria. The following method should be used to evaluate the results obtained from the simulator.

1. Calculate the average total run time for the MITRK program. (The average should consist of at least 5 sets of values.)
2. Compare the average with the calibration limits specified below.
3. Test results are considered acceptable if the average value falls within the calibration limits.

6.2.4.1.3 Calibration Limits. The 99% calibration limits for the average total run time of the MITRK program are 711 - 727 μs.

6.2.4.2 Test 12.2 - Parallel (AU) Time - 1 mip PEPE. Two tests have been specified for the parallel part of the MITRK program; one for the 1 mip PEPE and one for the .5 mip PEPE. The test conditions for the AU test are the same as those for the total time test except for the PEPE speed in the .5 mip test.

6.2.4.2.1 Acceptance Criteria

1. Calculate the average AU time for the MITRK program.
2. Compare average with calibration limits.
3. The simulator results are considered to be acceptable if the average AU time falls within the calibration limits specified below.

6.2.4.2.2 Calibration Limits. Analysis of the PHSD data shows that the average AU time for the MITRK program remains constant (to the nearest microsecond) under all conditions. The usual method of calculating the calibration limits requires the sample variance, which in this case turns out to be zero. Thus, the 99% (or any other calibration limit) calibration limits on the AU time would be the average AU time ± 0. This means that the results from the simulator must equal (exactly) the PHSD results in order to be acceptable. This requirement appears to be unreasonable. To allow the possibility of some variation, an arbitrary 2% variation has been specified. Therefore, the calibration limits for the 1 mip PEPE are 481 ±10μ or (471 - 491)μ.

6.2.4.3 Test 12.3 Parallel (AU) Time - .5 mip PEPE. The test for the .5 mip PEPE is the same as that for the 1 mip PEPE except that the calibration limits are 692 ± 14μ or (678 - 706)μ.

6.2.5 Test 13 - Guidance (GIDNC)

One test has been specified for the Guidance program - a test of the program total run under four conditions. The conditions to be tested are: no data, initialization of an element, performing guidance, guidance plus initialization.

6.2.5.1 Test Conditions. The test conditions for this test are:

Tracking rate - 20 Hz
PEPE speed - 1 mip
Host scale factor - 0.1
Radar block size - 2 ms
Threat - "In-house simulator"

6.2.5.2 Acceptance Criteria

6.2.5.2.1 No Data. The test for no data is a test of the average total program run time with no data being processed. This could also be called a null test. The procedure is as follows:

1. Calculate the average total (scaled) program run time. (The average should consist of at least 5 sets of values.)
2. Compare the average with the calibration limits specified below.
3. The test results are considered acceptable if the average value falls within the specified calibration limits.

Calibration Limits

The 99% calibration limits for the average total program run time for under the "no data" condition are (146 - 166μ).

6.2.5.2.2 Initialization. The initialization test for the average total GIDNC run time is exactly the same as the no data test except that the calibration limits have been changed to (716 - 763μ).

6.2.5.2.3 Guidance. The test of the "guidance" condition is the same as that for the "no data" condition except that the calibration limits for this test are (1843 - 1864μ).

6.2.5.2.4 Guidance and Initialization. The test for the "guidance and initialization" condition is the same as that for the "no data" condition except that the confidence limits for this test are (2412 - 2468μ).

6.2.6 Test 14 - Intercept Planning Control (INCTL)

One test has been specified for the Intercept Planning Control (INCTL) program. This test is for the average total program run time for one pass through the program. This test is limited; however, it is the best that can be performed with the data available.

6.2.6.1 Test Conditions. The test conditions for this test are:

Tracking rate - 20 Hz
PEPE speed - 1 mip
Host scale factor - 0.1
Radar block size - 2 ms
Threat - "In-house simulator"

6.2.6.2 Acceptance Criteria

1. Calculate the avera[illegible] total program run time for the "one pass through the program" condition. (At least 5 sets of values should be used to compute the average.)
2. Compare the average total program run with the calibration limits specified below.
3. The results from the simulator are considered to be acceptable if they fall within the calibration limits.

6.2.6.3 Confidence Limits. The 99% calibration limits for the total GIDNC run time for the "one pass through the program" condition are (2649 - 2810μ).

6.2.7 Test 15 - PEPE Accumulation Interval

The length of the accumulation interval in the track ensemble depends on several system parameters; e.g., tracking rate, radar block size. The accumulation interval test is designed to determine whether or not the calibration model accumulation interval is the same or close enough to that of the PHSD system. The specific situations to be tested are shown in Table 6.11. Tests 1,2 and 3 are required. Tests 4,5 and 6 are desirable.

6.2.7.1 <u>Test Conditions.</u>

Tracking rate - 20 Hz

PEPE speed - See Table 6.11

Host scale factor - See Table 6.11

Radar block size - See Table 6.11

Threat - "In-house simulator"

6.2.7.2 <u>Acceptance Criteria</u>

1. For each test identified in Table 6.11, calculate the average accumulation interval. (At least 30 values should be used to calculate the average.)
2. Compare the average accumulation interval with the calibration limits specified in Table 6.11
3. The results from the calibration model are acceptable if all of the values fall within the 99% calibration limit specified in Table 6.11

TESTS FOR PEPE ACCUMULATION INTERVAL				
TEST	HOST SCALE FACTOR	PEPE SPEED	RADAR BLOCK SIZE	AVERAGE ACCUM. INTERVAL (99% CL)
1	0.10	1 mip	2	36.32 - 38.06 ms
2	0.10	1 mip	6	18.15 - 19.89 ms
3	0.10	.5 mip	2	35.57 - 37.31 ms
4	0.10	1 mip	4	29.44 - 31.18 ms
5	0.25	1 mip	2	34.49 - 36.23 ms
6	0.25	1 mip	4	28.64 - 30.38 ms

Table 6.11

6.3 TYPE III TESTS - MISSION PROFILE CALIBRATION TESTS

The Component Calibration tests are designed to test specific individual components of the system under carefully controlled conditions. Only one component is tested in each test.

The Mission Profile tests test several components (in fact all components) in each test. The objective of the Mission Profile tests is to compare the results of a mission run on the simulator with the results of the same mission run on the PHSD equipment configuration at Whippany. We are primarily interested in comparing the results as a function of engagement time rather than some other calibration variable.

No formal acceptance criteria has been specified for the Type III tests. The reason for this is partly due to the availability of data and partly due to the lack (at least to the author's knowledge) of a suitable methodology (except for some trivial measures, which have most likely already been satisfied by the Type II tests). The selected course is acceptance by professional judgement; that is, an evaluator(s) will compare the results from the simulator with those obtained from the PHSD experiments and decide whether or not they are "close enough" for calibration purposes.

Only a limited number of Type III tests have been specified, since the calibration model must also pass the Type II tests. The experimentalists may want to consider other possibilities if time permits.

6.3.1 Test 16

The test conditions for test 16 are the same as those for PHSD experimental run 22 (See Appendix A for a description of the PHSD test runs). The test conditions are:

- Tracking rate - 20Hz
- PEPE speed - 1 mip
- Host scale factor - 0.1
- Radar block size - 2 ms
- Threat - "In-house simulator"
- Length of mission - at least 10 seconds

The following results should be collected from the simulator and compared with those obtained from the PHSD run 22:

1. Pulse Allocation - total run time
2. Target Track Processing - total run time
3. Track limitation - total run time
4. Guidance - total run time
5. Accumulation Interval - (length of)

6.3.2 Test 17

The conditions for test 17 are the same as those for test 16 except that the radar block size has been changed from 2 to 6 ms. This test corresponds to PHSD experimental test 20, (See Appendix A for a description of the PHSD test runs).

The results collected from test 17 are the same as those required for test 16.

6.3.3 Test 18

The conditions for test 18 are the same as those for test 16 except that the PEPE speed has been changed from 1 mip to .5 mip. This test corresponds to PHSD experimental test 33, (See Appendix A for a description of the PHSD test runs).

The results collected from test 18 are the same as those required for test 16.

APPENDIX A

PHSD EXPERIMENTS

Nine of the PHSD experiments performed at BTL in Whippany, New Jersey during August and September 1971 provided the data that was used to calculate the calibration limits for the calibration tests.

These experiments are summarized below. The "in house simulator" refers to a 21 object threat developed by BTL for checkout purposes. No data link with GRC is required for this test.

<u>Run 19 (August 29, 1971)</u>

Threat - GRC scenario 14 (60 objects in track)
Radar block - 2 ms
PEPE - 1 mip
Host scale factor - 0.25
No missiles

<u>Run 20 (August 31, 1971)</u>

Threat - In house simulator (21 object)
Radar block - 6 ms
PEPE - 1 mip
Host scale factor - 0.1

<u>Run 21 (August 31, 1971)</u>

Threat - GRC scenario 12
Radar block - 6 ms
PEPE - 1 mip
Host scale factor - 0.1

<u>Run 22 (September 1, 1971</u>

Threat - In hous simulator
Radar block - 2 ms
PEPE 1 mip
Host scale factor - 0.10

<u>Run 26 (September 3, 1971)</u>

Threat - In house simulator

Radar block - 1 ms

PEPE - 1 mip

Host scale factor - 0.25

<u>Run 27 (September 4, 1971)</u>

Threat - GRC scenario 15

Radar block - 6 ms

PEPE - 1 mip

Host scale factor - 0.10

<u>Run 28, (September 8, 1971)</u>

Threat - In house simulator

Radar block - 4 ms

PEPE - 1 mip

Host scale factor - 0.10

<u>Run 30 (September 8, 1971)</u>

Threat - GRC scenario 12

Radar block - 2 ms

PEPE - 1 mip

Host scale factor - 0.25

<u>Run 33 (September 14, 1971)</u>

Threat - In house simulator

Radar block - 2 ms

PEPE - 0.5 mip

Host scale factor - 0.10

APPENDIX B

CALCULATION OF THE PULSE ALLOCATION CALIBRATION LIMITS

Appendix B shows how the calibration limits were calculated for the Pulse Allocation program. Three sets of calibration limits are calculated; (1) Parallel (AU) time per millisecond for n objects in early or precision track (1 mip PEPE), (2) the same as (1) for 0.5 mip PEPE, and (3) the total (parallel and sequential) time for k track and interceptor pulses processed. Analysis of the PHSD experimental data shows that the above relationships are linear within certain limits. The calibration limits for the parallel time hold for 30 or fewer objects in track. For more objects in track, the relationship may not be linear. Analysis of Run 19 (60 objects in track) indicates that the relationship for large numbers of objects in track isn't linear.

The calibration limits for the total pulse allocation time hold for 25 or fewer pulses being processed. Whether or not the linear relationship holds for more than 25 pulses processed is not known at present.

1. Calibration limits - Parallel (AU) time for 1 mip PEPE

The calibration limits for the amount of time (parallel time) required to allocate pulses for n objects in early or precision track were obtained from an analysis of the PHSD experimental data. The data from eight test runs were utilized; Test runs 19, 20, 21, 22, 26, 27, 28 and 30.

The data from these tests represent a varity of test conditions which are summarized below:

Threat - In house simulator, CRC Sc 12, 14 and 15

Radar block - 1, 2, 4, 6 ms

Host scale factor - 0.25 and 0.10

The one common condition is, of course, the 1 mip PEPE.

Standard regression theory has been used to determine the linear relationship and estimate the variance. The data has been normalized by using sample averages only. All data shown in Table B-1 represents sample averages of

5 or more executions of pulse allocation.

The data in Table B-1 was obtained from the PHSD experiments. It shows the average AU time (μs) per millisecond of accumulation interval for n objects in early or precision track.

In PHSD, all radar pulses (search, track, and interceptor) were allocated in the track ensemble. The data collection facilities, however, did not keep track of the number of interceptors for which pulses were being allocated. It only recorded the number of objects (targets) in early or precision track. Therefore, the data in all test runs (except run 19 in which no interceptors are launched) contains the time required to allocate some unknown number (but usually small) of interceptor pulses. This tends to make the AU time larger than it should be for n objects in track. This situation is especially evident in Run 27 in which a relatively large number of interceptors (compared to the number of targets) are launched early in the scenario. Never the less, all of the data was used in order to estimate the variance. This situation will cause the AU time obtained from the model to appear low when the data does not contain any interceptor allocation time.

PULSE ALLOCATION

AVERAGE AU TIME (μs) PER MILLISECOND

ACCUMULATION INTERVAL FOR n OBJECTS IN TRACK

OBJECTS IN TRACK	PHSD RUN NUMBER							
	19	20	21	22	26	27	28	30
0			55.6			55.7		55.1
1						60.2		
2						62.0		
3			59.6			63.5		59.1
4	58.7					64.1		
5						64.5		
6			64.0			69.0		65.1
7			67.6			70.9		66.2
8			68.4			71.0		67.0
9			69.9			73.5		68.4
10			70.8			69.9		70.9
11			70.4			75.5		70.8
12	70.8					75.3		
13		72.7		72.1	72.2	72.3	72.4	
14		76.4		75.6		75.6	75.0	
15		77.6			76.9	74.1	77.2	
16						75.8		
17						79.0		
18		76.2				78.0		
19		79.5			78.3	77.7	77.8	
20		81.9		77.5	77.7		79.2	

TABLE B-1

OBJECTS IN TRACK	PHSD RUN NUMBER							
	19	20	21	22	26	27	28	30
21		83.0		82.3	82.1		80.7	
22	83.2	88.0		84.2	86.8		83.5	
23	83.3	89.2			85.1		87.8	
24	83.7	91.7					86.2	
25	82.2	88.3		87.6				
26		93.3		86.2			87.9	
27		89.3					93.8	
28								
29	90.2							
30								
31								
32								
33								
34	94.8							
35	97.1							
36	103.7							
37	98.9							
38								
39								
40								

TABLE B-1 (continued)

OB. :S]	PHSD RUN NUMBER							
	19	20	21	22	26	27	28	30
41	100.3							
42	99.6							
43	100.1							
44								
45	103.5							
46	107.7							
47	107.1							
48	108.0							
49								
50								
51								
52	106.4							
53								
54								
55								
56	114.2							
57	110.7							
58	115.5							
59	116.0							
60								

TABLE B-1 (continued)

Standard regression techniques will be used to determine the relationship between AU time and the number of objects in track. The independent variable χ is the number of objects in track. The dependent variable y, is the observed AU time. Since we have multiple observations for several values of χ we are able to test for linear fit.

Regression equation

The linear relationship is:

$$y = a + b\,(\chi - \bar{\chi})$$

where:

$$a = \frac{\Sigma\, yi}{n}$$

$$b = \frac{\Sigma\, \chi i y i - \frac{(\Sigma \chi i)\,(\Sigma y i)}{n}}{\Sigma\, \chi i^2 - \frac{(\Sigma \chi i)^2}{n}}$$

$$\chi = \frac{\Sigma \chi i}{n}$$

n = number of observations

= 80

Note: The summation limits have not been explicitely indicated on the above equations since they are all from 1 to n.

Calculating the various values from the data obtained from Table B-1 we have

$\Sigma yi = 6031.8$

$\Sigma y^2 i = 461{,}680.70$

$\Sigma \chi i = 1173$

$\Sigma \chi i\ yi = 93{,}940.$

$\Sigma \chi i^2 = 21{,}903$

$N = 80$

Thus

$$a = \frac{6031.8}{80} = 75.398$$

$$b = 1.169$$

$$\bar{\chi} = \frac{1173}{80} = 14.663$$

To estimate the variance we let

$$Q = \Sigma yi \quad - \quad a\Sigma yi - b[\Sigma \chi iyi - \frac{(\Sigma \chi i)\ (\Sigma yi)}{n}]$$

$$= 465.30$$

where Q is the sum of squares (SS) of the observations from the regression line, the estimated variance is

$$\hat{\sigma}^2 = \frac{Q}{M-2} = \frac{465.3}{78} = 2.44$$

Substituting into the above regression equation we get

$$y = a + b(\chi - \bar{\chi})$$

$$= 75.398 + 1.169\ (\chi - 14.663)$$

$$= 58.255 + 1.169\ \chi$$

where

y is the expected AU time, and χ is the number of objects in track. The 95% upper and lower calibration limits are obtained by adding $2\hat{\sigma}$ to the expected value. Thus the upper 95% calibration limit is

$$y_{\overline{95}} = 58.255 + 1.169\ \chi + 2(2.44)$$

$$= 63.135 + 1.169\ \chi$$

Similarily the lower 95% calibration limit is

$$y_{\underline{95}} = 58.255 + 1.169\ \chi - 2(2.44)$$

$$= 53.375 + 1.169\ \chi$$

Linear Fit Test

To see whether or not a linear model fits the data we proceed as follows.

If the underlying relationship is not linear then the mean (or expected value) of the distributions for some values of χ will not be on the regression line. If this is the case, then part of the total sum of square (Total SS) .Q. is accounted for by a shift of the mean of some of the distribution away from the regression line. We can check this by partiting the total SS (Q) into the components; one which estimates the Pure Error SS (sum of squares) and one which estimates the Lack of Fit SS and then use the F-test to see whether or not the variation is significant.

We calculate the Pure Error SS from those entries in Table B-1 which have more than one observation. The Pure Error SS for each such entry is

$$\text{Pure Error SS} = \Sigma(yij - \overline{y}j)^2$$

where yij is the i^{th} observation in the j^{th} entry in Table B-1 and $\overline{y}j$ is the average of all the observations in the j^{th} entry.

The number of degrees of freedom associated with each entry is one less than the number of observations.

The Pure Error SS and corresponding degrees of freedom for the data contained in Table B-1 is shown in Table B-2.

ALLOCATION AU

PURE ERROR SUM OF SQUARES

OBJECTS IN TRACK	DEGREES OF FREEDOM	PURE ERROR SS
0	2	.21
3	2	11.61
4	1	14.58
6	2	13.81
7	2	11.65
8	2	8.24
9	2	13.74
10	2	.61
11	2	17.42
12	1	10.12
13	4	.22
14	3	.99
15	3	7.61
18	1	1.62
19	3	2.05
20	3	12.37
21	3	2.79
22	4	18.28
23	3	21.09
24	2	33.50
25	2	22.29
26	2	27.49
27	1	10.12
TOTAL	52	262.41

TABLE B-2

The Lack of Fit SS is Total SS - Pure Error SS

$$= 465.30 - 262.41 = 202.89$$

Putting this data into an analysis of variance table representation we have

A of V

SOURCE	DF	SS	E(MS)
Regression	1		
Lack of Fit	26	202.89	202.89/26 = 7.803
Pure Error	52	262.41	262.41/52 = 5.046
TOTAL	N-1=79		

The standard F test can be used to test linearity of fit if

$\frac{7.803}{5.046} > F_{52}^{26}$ (1-α), then we reject the hypothesis that a linear model is satisfactory at the 1-α) confidence level.

$$\frac{7.803}{5.046} = 1.546.$$

Since $F_{52}^{26}(.95)$ is not in the F tables, we show that the data passes the linear fit test by noting that

$$F_{60}^{30}(.95) = 1.65 < F_{52}^{26}(.95)$$

Since 1.546 < 1.65 linear model is acceptable.

The estimated variance for each value of n(the number of objects in track) can be calculated from Table B-2 by dividing the SS by the corresponding degrees of freedom. This type of analysis shows that the estimate variance is independent of n.

2. Calibration Limits - Parallel (AU) time for .5 mip PEPE

The calibration limits for the .5 mip PEPE can be obtained from those for the 1 mip PEPE by multipling by a PEPE speed adjustment factor. One would expect that it would take the .5 mip PEPE twice as long to perform the same task as the 1 mip PEPE, however, due to the confusing PEPE mip ratings, that is not the case. The .5 mip PEPE that we are talking about is actually faster than .5 mip since it has a high speed multiply instruction.

Analysis of the parallel instructions executed for pulse allocation shows that the 1 mip PEPE is 1.7 time as fast as the .5 mip PEPE. Therefore, the .5 mip calibration limits are equal to the 1 mip calibration limits times 1.71. The 1.7 speed factor is only known to hold for 30 or fewer objects in track. For a larger number of objects in track it will increase because relatively speaking, fewer multiply instructions are executed.

3. Calibration limits - Total run time.

Analysis of the total ALLOC run time for the data obtained from PHSD run 22 shows that the relationship is linear for 8-25 pulses (track and interceptor) being processed. The data presented in Table B-3 is the average ALLOC time (milliseconds) to process h pulses. Note that we have repeated observations for most values of h shown.

AVERAGE ALLOC TIME FOR h PULSES

NUMBER PULSES PROCESSED	ALLOC - TOTAL RUN TIME (ms)
8	6.60
9	6.44, 6.50, 6.52, 6.52, 6.42
10	6.56, 6.80, 6.58, 6.68, 6.76, 6.86, 6.73
16	7.68, 7.62, 7.70, 7.62, 7.44, 7.26, 7.33
19	8.24, 7.62, 7.46
25	8.30

TABLE B-3

We will use the same method as outlined in 1 above to determine the linear relationship, estimate the varience, and determine whether or not a linear model is acceptable.

$$y = a + b(\chi - \bar{\chi})$$

$\Sigma\chi = 317$, $M = 24$ (# observations)

$\Sigma y = 170.24$

$\Sigma y^2 = 1215.458$

$\Sigma\chi y = 2307.08$

$\Sigma\chi^2 = 4669$

$\bar{\chi} = 13.2083$

$$a = \frac{170.24}{24} = 7.0933$$

$$b = 0.12136$$

$$Q = .7965$$

$$\hat{\sigma}^2 = s^2 = \frac{.7965}{22} = 0.0362$$

$$\hat{\sigma} = s = .1902$$

Thus

$$y = 7.0933 + 0.12136\ (\chi - 13.2083)$$

$$= 5.4903 + 0.12136\chi$$

where χ is the number of pulses processed

The upper and lower 95% calibrations limits are:

$$\overline{y_{95}} = 5.49 + 0.1214\ \chi + 2(.19)$$

$$= 5.87 + 0.1214\ \chi$$

$$\underline{y_{95}} = 5.49 + 0.1214\ \chi - 2(.19)$$

$$= 5.11 + 0.1214\ \chi$$

Lack of Fit Test

The lack of fit test for the total ALLOC run time is performed in the same way as above. The analysis of variance tables for this test is presented below.

A of V

SOURCE	DF	SS	E(MS)
Regression	1		
Lack of Fit	4	.1863	.1863/4 = .04658
Pure Error	18	.6102	.6102/18 = .0339
TOTAL	23		

We accept the linear model at the 95% level if

$$\frac{0.04658}{0.0339} = 1.374 < F_{18}^{4}\,(.95) = 2.93$$

Therefore the linear model is acceptable.

APPENDIX C

CALCULATION OF THE CALIBRATION LIMITS FOR TARGET TRACK PROCESSING (AU)

The method used to calculate the calibration limits for the target track processing program (TRKPRO) is the same as was used for pulse allocation (Appendix B).

1. Calibration limits - TRKPRO AU time (1 mip PEPE)

The calibration limits for TRKPRO AU time as a function of the number of objects in early or precision track were calculated from the data contained in Table C-1.

TARGET TRACK PROCESSING

AVERAGE AU TIME (MS) FOR n OBJECTS IN TRACK

OBJECTS IN TRACK	PHSD RUN NUMBER							
	19	20	21	22	26	27	28	30
0			3.56			3.57		3.57
1						3.58		
2						3.58		
3			3.57			3.59		3.58
4						3.59		
5						3.58		
6			3.58			3.59		3.60
7			3.59			3.60		3.62
8			3.59			3.60		3.61
9			3.60			3.61		3.61
10			3.60			3.58		3.63
11			3.59			3.61		3.61
12	3.57					3.61		
13		3.58		3.58	3.58	3.61		
14		3.60		3.64		3.62		
15		3.61			3.64	3.60		
16						3.60		
17						3.63		
18		3.62				3.62		
19		3.62			3.67	3.62		
20		3.62		3.67	3.66			

TABLE C-1

TARGET TRACK PROCESSING

AVERAGE AU TIME (MS) FOR n OBJECTS IN TRACK

OBJECTS IN TRACK	PHSD RUN NUMBER							
	19	20	21	22	26	27	28	30
21		3.61		3.64	3.65			
22	3.60	3.61		3.64	3.65			
23	3.60	3.61			3.65			
24	3.58	3.60						
25	3.57	3.62		3.67				
26		3.61		3.67			3.65	
27		3.63					3.64	

TABLE C-1 (continued)

Standard regression techniques were used.

The model is

$$y = a + b\ (\chi - \bar{\chi})$$

where a, b are calculated as in Appendix B

$$N = 70$$
$$\Sigma\chi = 998$$
$$\Sigma\chi^2 = 18497 \quad , \bar{\chi} = 14.2571$$
$$\Sigma y = 252.67$$
$$\Sigma y^2 = 912.0839$$
$$\Sigma\chi y = 3611.91$$

$$a = \frac{252.67}{70} = 3.6046$$

$$b = 0.0022397$$

$$Q = 0.0321$$

$$\hat{\sigma}^2 = \frac{0.0321}{68} = 0.000472$$

$$\hat{\sigma} = 0.0217$$

Therefore the expected TRKPRO run time (AU) is

$$y = 3.6096 + 0.0022397(\chi - 14.2571)$$
$$= 3.578 + 0.00224\ \chi$$

Where χ is the number of objects in early or precision track.

The slope for this equation is quite small, 0.00224, and it is natural to ask whether or not the slope could be zero. If the slope is zero, then the AU time is not dependent on the number of objects in track.

We can test for this possibility by calculating the 99% confidence interval for b. If this interval does not include zero, then we say that the slope is not zero. We use the t - statistic for this.

The 99% confidence interval for b is

$$b \pm t\,(.9995,68) \left[\frac{Q/N-2}{\Sigma(\chi i-\bar{\chi})^2}\right]^{1/2}$$

where

t (.9995,68) is the t - statistic with 68 degrees at the 99% confidence level.

and all other terms are as defined before.

Substituting in the appropriate values we have

99% confidence interval for b is b $\pm$ 0.00102, or that b is between 0.00122 and 0.00326.

Therefore b $\neq$ 0, hence the AU time depends on the number of objects in track.

Linear Fit Test

The linear fit test is performed in the same way as was done in Appendix B. We will only show the analysis of variance table here.

A of V

SOURCE	DF	SS	E(MS)
Regression	1		
Lack of Fit	42	0.0111	0.0111/42 = 0.000262
Pure Error	26	0.0210	0.0210/26 = 0.000808
TOTAL	69		

We accept the linear model if

$$\frac{0.000262}{0.000808} = 0.324 \leq F^{42}_{26}\,(.95) \simeq 1.87$$

Therefore we accept the linear model.

2. Calibration Limits - TRKPRO AU Time (.5 mip PEPE)

The .5 mip PEPE calibration limits for the target track processing AU time is obtained from the 1 mip calibration limits by adjusting the latter by a speed factor.

Since TRKPRO has a large number of multiply instructions and since the multiply times on the 1 mip and .5 mip PEPE are the same, we don't expect very much difference in the times.

Comparing the TRKPRO AU times in test, we find that the speed factor is 1.25.

Thus, the .5 mip TRKPRO calibration limits can be calculated from the 1 mip limits by multiplying by 1.25.

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PEPE FUNCTIONAL SIMULATION

CALIBRATION MODEL

CALIBRATION TES~ RESULTS

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1.0 INTRODUCTION

This document presents the results of the tests performed on the PEPE functional simulation calibration model. The model and a detailed description of the calibration tests are presented in TM-HU-048/500/00, PEPE Functional Simulation, Calibration Model, Detailed Test Plans.

1.1 RELATED DOCUMENTS

The detailed test plans and the results of the PEPE functional simulation are presented in a set of four related documents. These documents are:

PEPE Functional Simulation Calibration Model - Detailed Test Plans	TM-HU-048/500/00
PEPE Functional Simulation Calibration Model - Calibration Test Results	TM-HU-048/501/00
PEPE Functional Simulation System Verification Model - Detailed Test Plans	TM-HU-048/502/00
PEPE Functional Simulation System Verification Model - SVM Test Results	TM-HU-048/503/00

2.0 SUMMARY OF TEST RESULTS

The Calibration Model has successfully passed all calibration tests and is, therefore, said to be calibrated. All of the BMD Effectiveness test (Type I test) requirements were satisfied in a single test (test 8). All test results were within required limits.

The threat for this test contained 17 objects including radar attackers, non-radar threats and non-threatening objects. Three in-flight missile failures were incorporated into the test. In addition, the radar cross section on one of the radar attackers was set to zero for two seconds. The model performance with respect to the object (object 9) is noteworthy since the first interceptor assigned to this target experienced an in-flight (planned) failure near the time of zero radar cross section. The model responded by placing the object in Special Acquisition mode, planning and then committing a second interceptor for a successful kill. All object history times for this object are within required limits. The detailed results of the Type I tests are presented in Section 3.1.

The results of the Component Calibration tests (Type II tests) are presented in Section 3.2. These results show that all components of the model are calibrated. These results also show that the model responds properly to perturbations; e.g., to changes in PEPE speed or radar block size.

The results of the Type II tests show that the model is calibrated; that is, these tests show that the model results are within certain limits. By merely knowing that the model has successfully passed the Type II tests, one is still not sure how close the model results are to the measured data except to say that it must be within a certain percent. (We can determine the maximum variation by knowing that the model has passed the Type II tests.)

One way of determining the degree of closeness of the model to the data is to calculate the average variation between the model results and the

expected results for the Type II tests. These results (presented in Table 2.1) show that the average variation between the model results and the expected results range from a low of 0.5% for pulse allocation to a high of 13% for track initiation with an overall average variation of 3%. The high percentage variation for track initiation is a result of a small run time (100 - 200μs)and a modest deviation. (The results for the track initiate program are within the required calibration limits.)

The average variation of 3% means that the model values are very close to their expected values and is an indication of the fidelity of the model to the actual system.

The results of the Mission Profile Calibration (Type III) tests are presented in Section 3.3. The results of these tests also show the exactness by which the model results compare with the data. Indeed the most difficult task when studying these results is to distinguish between the model values and the original data.

TABLE 2-1

COMPARISON OF MODEL RESULTS WITH DATA

PROGRAM	AVERAGE VARIATION (%)
Pulse Allocation	
Parallel (AU) Only	5
Total	0.5
Track Initiation	13
Target Track Processing (KFLT)	
Parallel	0.5
Interceptor Track Processing (MITRK)	1
Guidance	1.3
Interceptor Plan Control	2
Average for All Programs	3

3.0 CALIBRATION TEST RESULTS

3.1 BMD EFFECTIVENESS TESTS (TYPE I)

The calibration model has successfully satisfied all Type I test requirements in one test - test number 8. The test was performed in accordance with the requirements specified in Section 6.1.7.8 of the test plan (TM-HU-048/500/00). The results of this test are presented in Table 3-1. They show that all times for all objects are within required limits. Therefore, the model has satisfied all Type I test requirements.

The test results for object 9 are worth noting since they illustrate the fidelity of the simulator to the PHSD engagement logic. Object 9 (a radar attacker) enters the search volume and is detected as usual and an interceptor is committed. The interceptor experiences an in-flight failure (planned), which is properly detected and a second intercept is planned. In the mean time the radar cross section for object 9 is set to zero and remains at zero for 2 seconds. The model places object 9 is Special Acquisition status and continues the second intercept. The second interceptor is committed and achieves a successful interception. All times reported by the model are within required limits.

3.2 COMPONENT CALIBRATION TESTS (TYPE II)

3.2.1 Test 9 - Pulse Allocation

The results of the three calibration tests for pulse allocation (described in the following paragraphs) show that the pulse allocation program is calibrated for both the 1 mip and 0.5 mip PEPE.

3.2.1.1 Test 9.1 - Parallel (AU) Time - 1 mip PEPE. The pulse allocation parallel (AU) test for the 1 mip PEPE was performed according to the specifications contained in Section 6.2.1.1 of the test plan (TM-HU-048/500/00). The results of this test are presented in Table 3-2. The results show that the parallel component of the pulse allocation program is calibrated. All of the results obtained from the model (except one) are within the 95% calibration limits. The one outside the required limits is only out

TABLE 3-1

TEST RESULTS - BMD EFFECTIVENESS TESTS - CALIBRATION MODEL

TEST NUMBER 8

ENGAGEMENT TIME (Sec) (after launch)	Model Times	FUNCTION
Object No. 1		
2982.00 - 2983.65	2982.79	Initial search/verify hits
2982.02 - 2983.67	2982.79	Track initiation
2982.12 - 2983.77	2982.92	Early track
2984.52 - 2986.17	2985.51	Precision track
2984.52 - 2987.27	2985.80	MAR sent
2984.67 - 2988.47	2986.73	LCS sent
2986.72 - 2990.67	2989.57	Missile track acquired
2993.17 - 2994.24	2993.60	Missile burst confirmed
2993.17 - 2994.79	2993.82	Target track dropped
Object No. 2		
2969.00 - 2972.58	2969.31	Initial search/verify hits
2969.02 - 2972.60	2969.31	Track initiation
2969.12 - 2972.70	2969.42	Early track
2971.52 - 2975.10	2971.94	Precision track
2971.52 - 2976.20	2972.04	MAR sent
2971.67 - 2977.40	2972.94	LCS sent
2973.72 - 2979.60	2975.77	Missile track acquired
2974.92 - 2981.20	2976.49	Missile failure detected
2974.92 - 2981.80	2976.60	MAR sent
2975.07 - 2983.00	2977.49	LCS sent
2977.12 - 2985.20	2980.32	Missile in track
2984.93 - 2987.01	2985.28	Missile burst confirmed
2984.93 - 2987.56	2985.35	Target track dropped

-- continued --

Table 3-1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 3		
2974.00 - 2976.20	2974.73	Initial search/verify hits
2974.02 - 2976.22	2974.73	Track initiation
2974.12 - 2976.32	2974.84	Early track
2976.52 - 2978.72	2977.43	Precision track
2976.52 - 2979.82	2977.57	MAR sent
2976.67 - 2981.02	2978.50	LCS sent
2978.72 - 2983.22	2981.33	Missile track acquired
2986.23 - 2988.92	2987.43	Missile burst confirmed
2986.23 - 2989.47	2987.58	Target track dropped
Object No. 4		
2974.00 - 2976.20	2974.89	Initial search/verify hits
2974.02 - 2976.22	2974.89	Track initiation
2974.12 - 2976.32	2974.99	Early track
2976.52 - 2978.72	2977.54	Precision track
2976.52 - 2979.82	2977.83	MAR sent
2976.67 - 2981.02	2979.62	LCS sent
2978.72 - 2983.22	2988.45	Missile track acquired
2986.97 - 2988.61	2987.47	Missile burst confirmed
2986.97 - 2989.16	2987.58	Target track dropped
Object No. 5		
2970.00 - 2973.58	2970.18	Initial search/verify hits
2970.02 - 2973.60	2970.18	Track initiation
2970.12 - 2973.70	2970.28	Early track
2972.52 - 2976.10	2972.87	Precision track
2972.52 - 2977.20	2973.05	MAR sent
2972.67 - 2978.40	2973.91	LCS sent
2974.72 - 2980.60	2976.74	Missile track acquired
2975.92 - 2982.20	2977.42	Missile failure detected
2975.92 - 2982.75	2977.60	Target track dropped

-- continued --

Table 3-1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 6		
2974.00 - 2976.20	2975.05	Initial search/verify hits
2974.02 - 2976.22	2975.05	Track initiation
2974.12 - 2976.32	2975.18	Early track
2976.52 - 2978.72	2977.73	Track while scan
2979.63 - 2981.83	2977.77	Drop track while scan
Object No. 7		
2973.00 - 2975.20	2973.32	Initial search/verify hits
2973.02 - 2975.22	2973.32	Track initiation
2973.12 - 2975.32	2973.42	Early track
2975.52 - 2977.72	2975.97	Track while scan
2978.63 - 2980.83	2979.02	Drop track while scan
Object No. 8		
2975.00 - 2977.20	2975.37	Initial search/verify hits
2975.02 - 2977.22	2975.37	Track initiation
2975.12 - 2977.32	2975.48	Early track
2977.52 - 2979.72	2978.13	Track while scan
2980.63 - 2982.83	2980.70	Drop track while scan
Object No. 9		
2971.00 - 2974.58	2973.59	Initial search/verify hits
2971.02 - 2974.60	2973.59	Track initiation
2971.12 - 2974.70	2973.72	Early track
2973.52 - 2977.10	2976.27	Precision track
2973.52 - 2978.20	2976.60	MAR sent
2973.67 - 2979.40	2977.45	LCS sent
2975.72 - 2981.60	2980.28	Missile track acquired
2976.92 - 2983.20	2980.81	Missile failure detected
2976.92 - 2983.80	2981.07	MAR sent
2977.07 - 2985.00	2982.17	LCS sent
2979.12 - 2987.20	2985.02	Missile in track

— continued —

Table 3-1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 9 (cont'd.)		
2980.15 - 2980.25	2980.18	Special acquisition
2982.00 - 2982.25	2982.24	Precision track or track initiation
2986.93 - 2989.01	2988.06	Missile burst confirmed
2986.93 - 2989.56	2988.35	Target track dropped
Object No. 10		
2973.00 - 2975.20	2973.63	Initial search/verify hits
2973.02 - 2975.22	2973.63	Track initiation
2973.12 - 2975.32	2973.76	Early track
2975.52 - 2977.72	2976.31	Precision track
2975.52 - 2978.82	2976.60	MAR sent
2975.67 - 2980.02	2977.49	LCS sent
2977.72 - 2982.22	2980.31	Missile track acquired
2986.60 - 2988.18	2986.62	Missile burst confirmed
2986.60 - 2988.68	2986.84	Target track dropped
Object No. 11		
2973.00 - 2975.20	2973.79	Initial search/verify hits
2973.02 - 2975.22	2973.79	Track initiation
2973.12 - 2975.32	2973.91	Early track
2975.52 - 2977.72	2976.46	Precision track
2975.52 - 2978.82	2976.60	MAR sent
2975.67 - 2980.02	2977.42	LCS sent
2977.72 - 2982.22	2980.27	Missile track acquired
2986.39 - 2988.03	2986.51	Missile burst confirmed
2986.39 - 2988.58	2986.58	Target track dropped

— continued —

Table 3-1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 12		
2974.00 - 2976.20	2975.86	Initial search/verify hits
2974.02 - 2976.22	2975.86	Track initiation
2974.12 - 2977.32	2975.96	Early track
2976.52 - 2978.72	2978.58	Precision track
2976.52 - 2979.82	2978.90	MAR sent
2976.67 - 2981.02	2979.77	LCS sent
2978.72 - 2983.22	2982.79	Missile track acquired
2986.55 - 2989.45	2988.43	Missile burst confirmed
2986.55 - 2990.00	2988.57	Target track dropped
Object No. 13		
2978.00 - 2980.20	2979.81	Initial search/verify hits
2978.02 - 2980.22	2979.81	Track initiation
2978.12 - 2980.32	2979.93	Early track
2980.52 - 2982.72	2982.52	Track while scan
2982.23 - 2984.43	2982.62	Drop track while scan
Object No. 14		
2975.00 - 2976.65	2976.28	Initial search/verify hits
2975.02 - 2976.67	2976.29	Track initiation
2975.12 - 2976.77	2976.41	Early track
2977.52 - 2979.17	2978.92	Track while scan
2980.65 - 2982.30	2988.91	Drop track while scan

-- continued --

Table 3-1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 15		
2974.00 - 2975.65	2974.85	Initial search/verify hits
2974.02 - 2975.67	2974.85	Track initiation
2974.12 - 2975.77	2974.96	Early track
2976.52 - 2978.17	2977.57	Precision track
2976.52 - 2979.27	2977.79	MAR sent
2976.67 - 2980.47	2978.73	LCS sent
2978.72 - 2982.67	2981.57	Missile track acquired
2985.81 - 2986.86	2986.06	Missile burst confirmed
2985.81 - 2987.41	2986.36	Target track dropped
Object No. 16		
2973.00 - 2975.20	2974.26	Initial search/verify hits
2973.02 - 2975.22	2974.26	Track initiation
2973.12 - 2975.32	2974.39	Early track
2975.52 - 2977.72	2976.98	Track while scan
2978.63 - 2980.83	2979.02	Drop track while scan
Object No. 17		
2975.00 - 2977.20	2976.33	Initial search/verify hits
2975.02 - 2977.22	2976.33	Track initiation
2975.12 - 2977.32	2976.45	Early track
2977.52 - 2979.72	2978.96	Precision track
2977.52 - 2980.82	2979.06	MAR sent
2977.67 - 2982.02	2979.96	LCS sent
2979.72 - 2984.22	2982.81	Missile track acquired
2987.55 - 2990.13	2988.88	Missile burst confirmed
2987.55 - 2990.63	2989.09	Target track dropped

TABLE 3-2

TEST RESULTS

PULSE ALLOCATION - PARALLEL TIME (1 MIP PEPE)

OBJECTS IN TRACK	MODEL	PARALLEL TIME (μ)/ms ACCUM. INTERVAL 95% CALIBRATION LIMITS
0	62	53 - 63
4	66	58 - 68
7	64	62 - 71
10	67	65 - 75
13	68	69 - 78
15	72	71 - 81
19	76	76 - 85
21	78	78 - 88
22	79	79 - 89

by 1μs. The reason for this and the fact that some results are on the low side of the expected value is that the model results do not include allocation time for interceptors whereas the calibration limits are based on data which includes the allocation time for some unknown number of interceptors (See Appendix B of TM-HU-048/500/00 for a further discussion of this situation).

3.2.1.2 Test 9.2 - Parallel (AU) Time - 0.5 mip PEPE. The pulse allocation parallel (AU) test for the .5 mip PEPE was performed according to the specifications contained in Section 6.2.1.2 of the test plan. The results of this test are presented in Table 3-3. The results show that the parallel component of the pulse allocation program is also calibrated to the .5 mip PEPE since they are all within the 95% calibration limits.

3.2.1.3 Test 9.3 - Pulse Allocation - Total Run Time. The test of the total run time for the pulse allocation program was performed according to the specifications contained in Section 6.2.1.3 of the test plan. The results of this test are presented in Table 3-4. All of the model values are within their respective 95% calibration limits. Therefore, the pulse allocation program is considered to be calibrated.

3.2.2 Test 10 - Track Initiation

The track initiation test was performed according to the specifications contained in Section 6.2.2 of the test plan. The results of this test are presented in Table 3-5. The test results are within the specified calibration limits, therefore the track initiation program is considered to be calibrated.

3.2.3 Test 11 - Target Track Processing

The results of the calibration tests performed on the target track processing program (Kalman filter) show that the parallel component of the program is calibrated to both the 1 and 0.5 mip PEPE.

TABLE 3-3

TEST RESULTS

PULSE ALLOCATION - PARALLEL TIME (.5 MIP PEPE)

OBJECTS IN TRACK	MODEL	PARALLEL TIME (μ)/ms ACCUM. INTERVAL 95% CALIBRATION LIMITS
0	106	90 - 107
4	111	99 - 116
7	109	105 - 121
10	113	111 - 128
13	116	117 - 133
15	121	121 - 138
19	129	129 - 145
21	133	133 - 150
22	135	134 - 151

TABLE 3-4

TEST RESULTS

PULSE ALLOCATION - TOTAL TIME

PULSES PROCESSED	MODEL	TOTAL TIME (ms) 95% CALIBRATION LIMITS
8	6.40	6.08 - 6.84
9	6.58	6.20 - 6.96
10	6.70	6.32 - 7.08
11	6.79	6.45 - 7.21
12	6.88	6.57 - 7.33
13	7.12	6.69 - 7.45
14	7.25	6.81 - 7.57
15	7.32	6.93 - 7.69
16	7.43	7.05 - 7.81
17	7.62	7.17 - 7.93
18	7.65	7.30 - 8.06
19	7.80	7.42 - 8.18
20	7.87	7.54 - 8.30

TABLE 3-5

TEST RESULTS

TRACK INITIATION - TOTAL RUN-TIME

PROGRAM STATE	(μ Sec) MODEL	99% CALIBRATION LIMITS
TI 0 obj.	144	106 - 144
TI ≥ 1 obj.	246	202 - 246

3.2.3.1 Test 11.1 - Parallel (AU) Time - 1 mip PEPE. The test for the parallel component of the Target Track Processing program was performed according to the specifications contained in Section 6.2.3.1 of the test plan. The results are presented in Table 3-6. All of the test results are within the 95% calibration limits, therefore the TRKPRO parallel component for the 1 mip PEPE is considered to be calibrated.

3.2.3.2 Test 11.2 - Parallel (AU)Time - 0.5 mip PEPE. The test for the parallel component of the Target Track Processing program for a 0.5 mip PEPE was performed according to the specifications contained in Section 6.2.3.2 of the test plan. The results of this test are presented in Table 3-7. All of the test results fall within the 95% calibration, therefore the parallel component for the 0.5 mip PEPE is also considered to be calibrated.

3.2.4 Test 12 - Interceptor Track Processing (MITRK)

The test results obtained from the model show that the total run time and parallel component of the Interceptor Track Processing program is calibrated to both the 1 mip and 0.5 mip PEPE.

3.2.4.1 Test 12.1 - Total Run Time. The total run time test for the Interceptor Track processing program (MITRK) was performed according to the specifications contained in Section 6.2.4.1 of the test plan. The test results are presented in Table 3-8. The results are within the calibration limits, therefore the program is considered to be calibrated.

3.2.4.2 Test 12.2 - Parallel (AU) Time - 1 mip PEPE. The AU test for the Interceptor Track Processing program for the 1 mip PEPE was performed according to the specifications contained in Section 6.2.3.2 of the test plan. The results (presented in Table 3-8) show that the parallel component of the MITRK program is calibrated to the 1 mip PEPE.

3.2.4.3 Test 12.3 - Parallel (AU) Time - .5 mip PEPE. The AU test for the Interceptor Track Processing program for the 0.5 mip PEPE was performed according to the specifications contained in Section 6.2.3.2 of the test plan. The results are presented in Table 3-8. They show that the parallel component of the MITRK program is also calibrated to the 0.5 mip PEPE.

TABLE 3-6

TEST RESULTS
TARGET TRACK PROCESSING (KALMAN FILTER)
PARALLEL TIME – (1 MIP PEPE)

OBJECTS IN TRACK	PARALLEL TIME (ms) MODEL	95% CALIB. LIMITS
0	3.57	3.53 - 3.62
4	3.57	3.54 - 3.63
7	3.57	3.55 - 3.64
10	3.57	3.56 - 3.64
13	3.57	3.56 - 3.65
15	3.63	3.57 - 3.65
19	3.64	3.58 - 3.66
21	3.63	3.58 - 3.67
22	3.66	3.58 - 3.67

TABLE 3-7

TEST RESULTS

TARGET TRACK PROCESSING (KALMAN FILTER)

PARALLEL TIME - (0.5 MIP PEPE)

OBJECTS IN TRACK	MODEL	95% CALIBRATION LIMITS
0	4.477 (ms)	4.417 - 4.526 (ms)
3	4.477	4.425 - 4.534
5	4.477	4.431 - 4.540
8	4.477	4.439 - 4.548
12	4.477	4.451 - 4.560
13	4.477	4.453 - 4.562
15	4.562	4.459 - 4.568
19	4.569	4.569 - 4.579
21	4.582	4.476 - 4.585
22	4.583	4.478 - 4.588
25	4.580	4.487 - 4.596
26	4.587	4.490 - 4.599

TABLE 3-8

TEST RESULTS

INTERCEPTOR TRACK PROCESSING (MITRK)

TEST	MODEL	(μ Sec) CALIBRATION LIMITS
Total Run Time	717	711 - 727 (μ)
Parallel - 1 mip PEPE	489	471 - 491
Parallel - .5 mip PEPE	695	678 - 706

3.2.5 Test 13 - Guidance

The Component Calibration Test for the Guidance Program was performed according to the specifications contained in Section 6.2.5 of the test plan. The test results are presented in Table 3-9. The model results for two of the four program states are within the required calibration limits. Although the model results for the other two program states are outside the calibration limits, the results from the model do show that the model run times behave properly, that is, they follow the expected pattern. The precentage variation between the model results and the expected values is small (less than 3%).

The reason for the variation is not readily apparent. It could be in the model although that seems unlikely in view of the results of the other tests. It could also be in the original data. Since the original data is summarized according to the number of objects in track, the data for the Guidance program had to be obtained from the time line printouts which do not identify the program state.

The Guidance program is however, considered to be calibrated.

3.2.6 Test 14 - Interceptor Planning Control

The Calibration Test for the Interceptor Planning Control Program was performed according to the specifications contained in Section 6.2.6 of the test plan. The results show that the model values are within the required calibration limits. The Interceptor Planning Control program is considered to be calibrated. Test results are shown in Table 3-10.

It should be noted that the scope of this test is quite limited. The reason for this is that the program run time is a complex function of 3-dimensional geometry and engagement time which is extremely difficult to replicate with a 2-dimensional radar model.

3.2.7 Test 15 - PEPE Accumulation Interval

The test for the PEPE accumulation interval was performed according to the specifications contained in Section 6.2.7 of the test plan. The test results are presented in Table 3-11. The results of this test show that the PEPE scheduling algorithm in the model is the same (within limits) as that in the PHSD demonstration system. This test shows that the scheduler makes the proper adjustment for changes in the speed of the host, speed of PEPE and the size

TABLE 3-9

TEST RESULTS

GUIDANCE - TOTAL RUN TIME

STATE	MODEL	(μ Secs) 99% CALIBRATION LIMITS
NO DATA	159	146 - 166
INITIALIZATION	737	716 - 763
GUIDANCE	1895	1843 - 1864 *
G & I	2473	2412 - 2468 *

TABLE 3 - 10

TES1 RESULTS

INTERCEPTOR PLANNING CONTROL - TOTAL RUN TIME

STATE	MODEL	99% CALIBRATION LIMITS (ms)
SINGLE PASS	2.78	2.65 - 2.81

TABLE 3-11

TEST RESULTS

PEPE ACCUMULATION INTERVAL

TEST	MODEL	(ms) 99% CALIBRATION LIMITS
1	37.40	36.32 - 38.06
2	19.51	18.15 - 19.89
3	36.06	35.57 - 37.31

of the radar block.

3.3 MISSION PROFILE CALIBRATION TESTS (TYPE III)

The Mission Profile Calibration tests were preformed according to the specificat ons contained in Section 6.3 of the test plan. These tests (Figures 1-9) show that the model results are very close to the measured results obtained from the PHSD demonstration system. Since no specific acceptance criteria was specified for the Type III tests, the reader must examine the results and subjectively decide whether or not the model results are close enough to the observed results to say that the model is calibrated. In the judgement of the author, they are close enough and the model is considered to be calibrated.

Three Mission Profile Calibration Tests have been designed to determine how well the model responds to changes in two basic system parameters; PEPE speed and radar block size.* The result of the following tests show that the model does respond as expected to the various perturbations.

3.3.1 Test 16 (PHSD Run 22)

Calibration Test 16 corresponds to PHSD Run 22. The PEPE speed and radar block size for this test are 1 mip and 2 ms respectively. A comparison of the model results and the PHSD data for the Pulse Allocation, Track Initiation, Target Track Processing (Kalman Filter), and Missile Tracking Programs for Test 16 is presented in Figures 1-3. The data in Figures 1-3 show the execution time of the tactical programs as a function of engagement time. Figure 1 also presents a comparison of the PEPE accumulation interval and the number of pulses that must be processed each cycle. (The curve labeled Data in Figure 1).

The model results for the Kalman Filter are so close to the PHSD data (figure 1) that its hard to distinguish the two curves. The results for pulse allocation are equally impressive expecially when one considers the iterative nature of the allocation process. The apparent deviation of the pulse allocation model

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* The Type II tests also check this response. Since the model has passed all type II tests, a good agreement between the model results and PHSD data is expected.

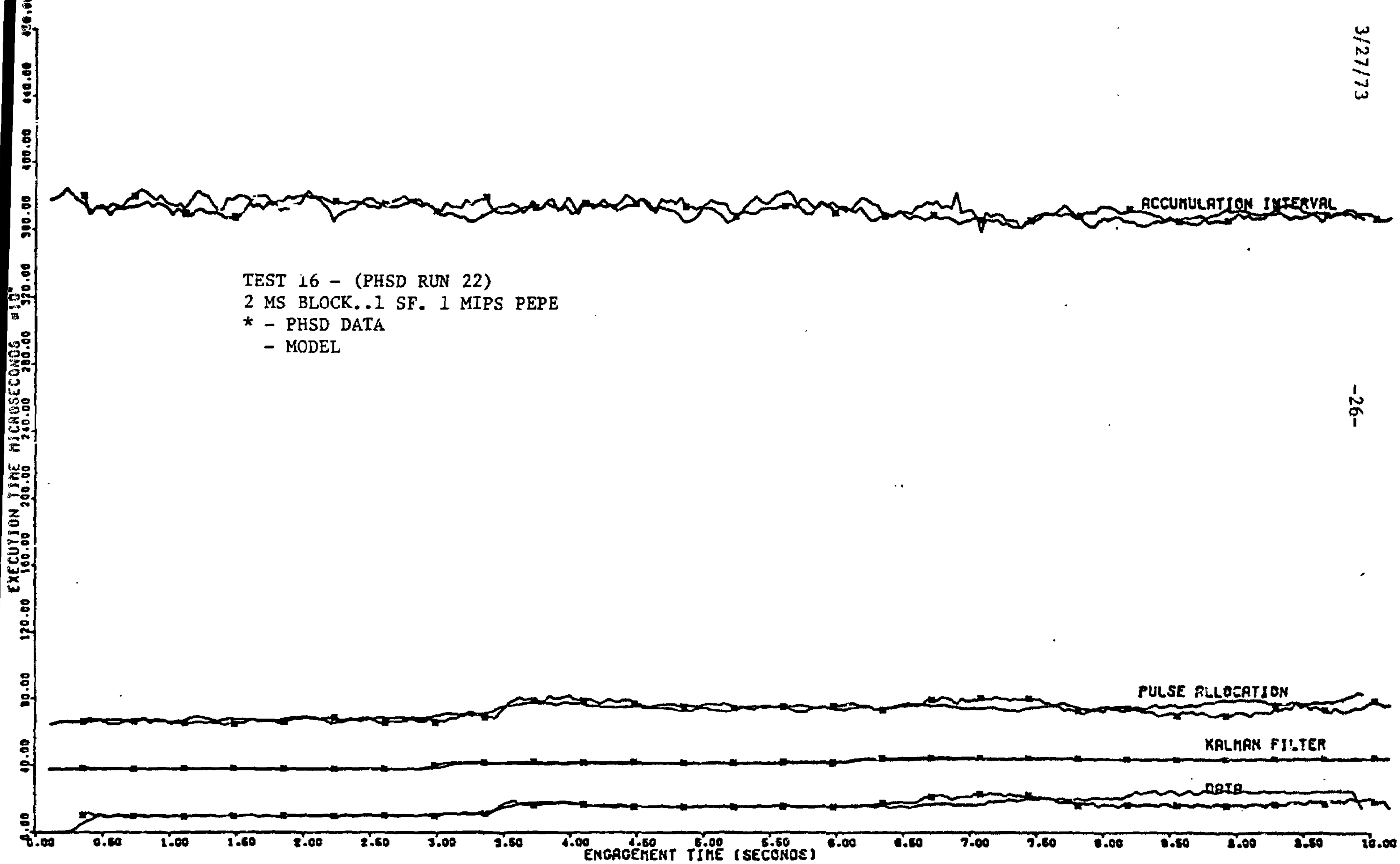
ACCUMULATION INTERVAL
TEST 16 - (PHSD RUN 22)
2 MS BLOCK..1 SF. 1 MIPS PEPE
* - PHSD DATA
- MODEL
PULSE ALLOCATION
KALMAN FILTER
DATA
EXECUTION TIME MICROSECONDS *10
ENGAGEMENT TIME (SECONDS)

FIGURE 1

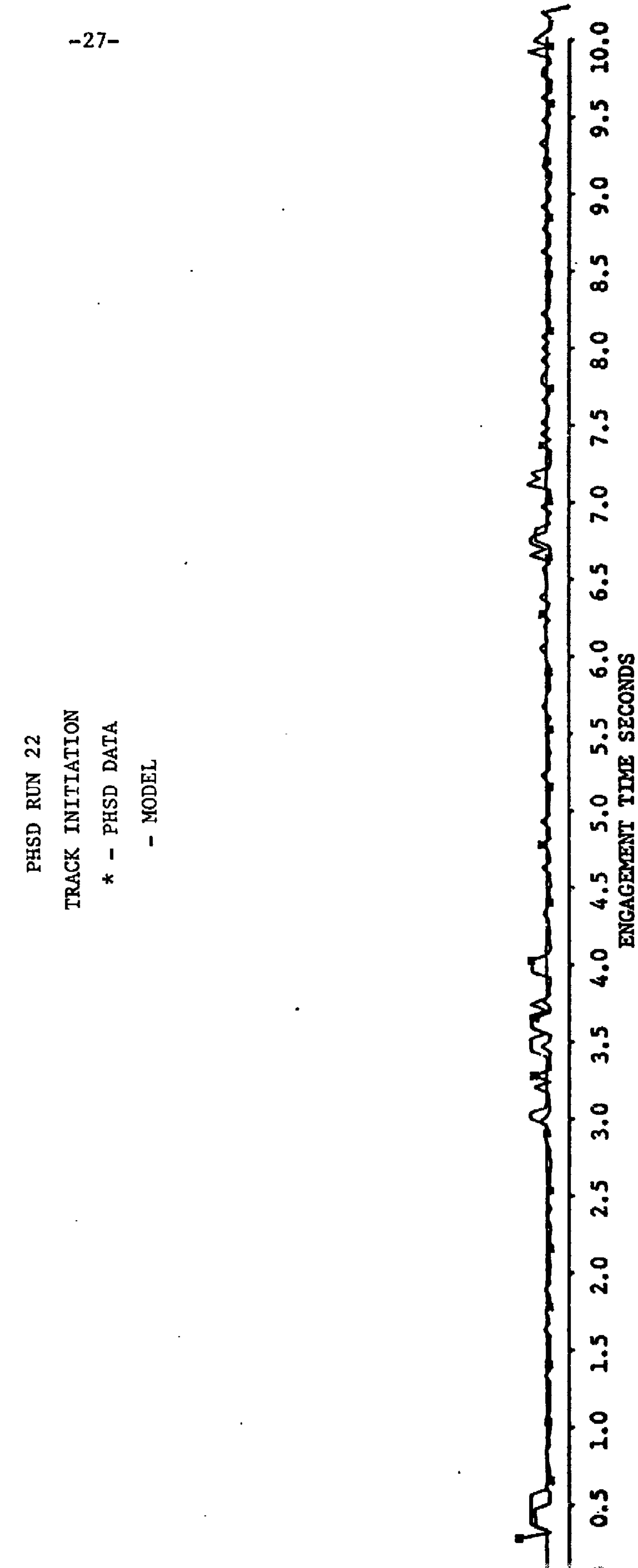
PHSD RUN 22
TRACK INITIATION
* - PHSD DATA
- MODEL
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
ENGAGEMENT TIME SECONDS

FIGURE 2

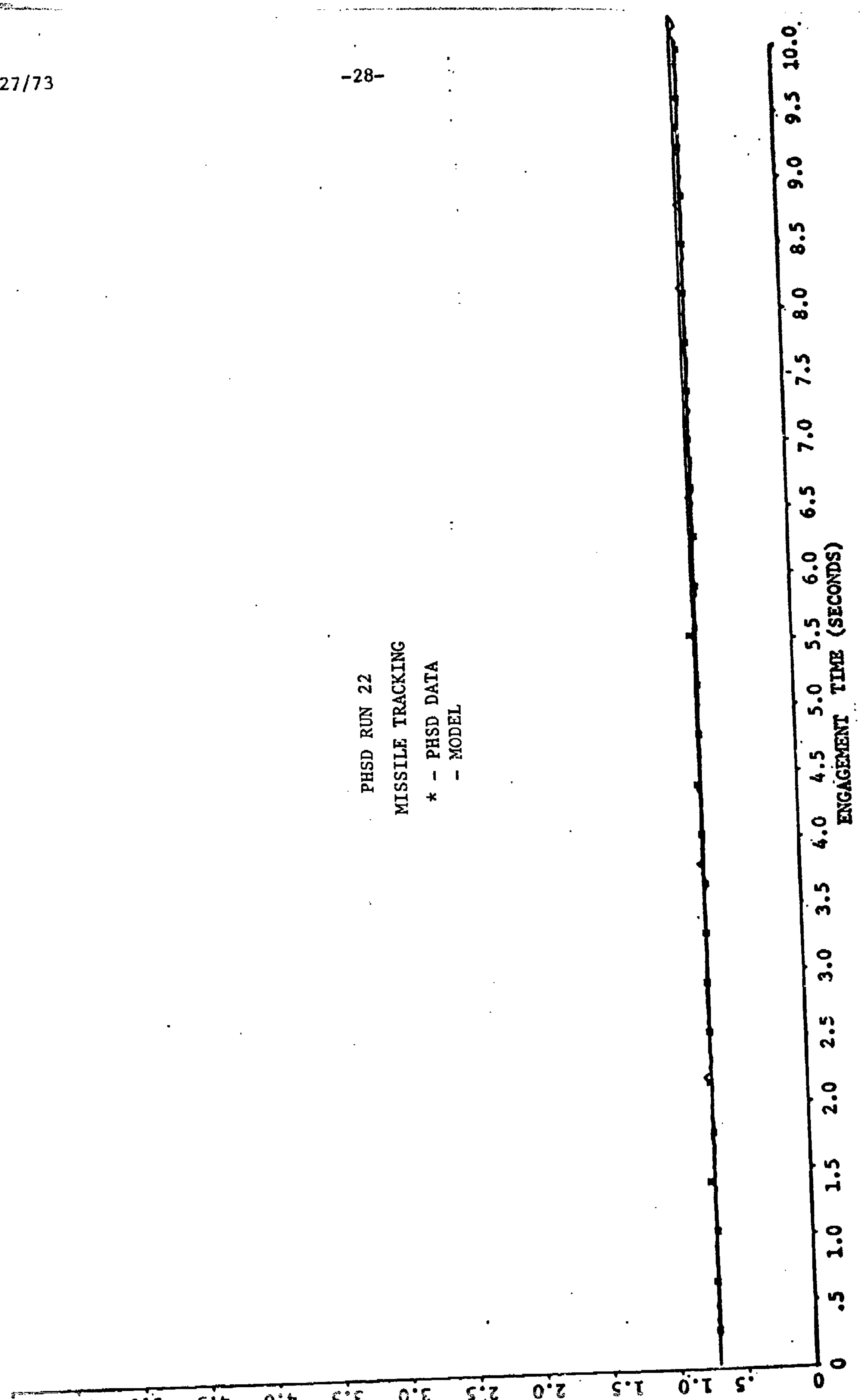
PHSD RUN 22
MISSILE TRACKING
* - PHSD DATA
- MODEL
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
ENGAGEMENT TIME (SECONDS)
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

FIGURE 3

results from the PHSD data around 7 and 9 seconds is not the result of calibration difficulties in the pulse allocation program but rather the result of certain difficulties that arise with the two-dimensional radar model. This is evidenced by the fact that there is a corresponding difference in the data curves during these times. The model pulse allocation time adjusted for the difference on the data curves would be much closer in the 7 and 9 second range. However, the model results are very impressive and must be considered to be close enough for calibration even if one ignores the limited geometry in the radar model.

The PEPE accumulation interval obtained from the model for this test is very close to that measured in the PHSD demonstration system. These two curves are so closely intertwined (figure 1) that its hard to tell one from the other. The results for the Track Initiation and Missile Tracking Programs are presented in Figures 2 and 3 respectively. In both cases, the model results are very close to the measured results obtained from the PHSD demonstration system.

3.3.2 Test 17 (PHSD Run 20)

Test 17 corresponds to PHSD Run 20. All System Parameters in this test are the same as in Test 16 except for the radar block size which has been increased from 2 to 6 ms. Increasing the radar block size should cause the accumulation interval to become shorter which in turn reduces the load per execution of the pulse allocation program and hence will decrease its run time per execution. The run time for the Kalman Filter, Track Initiation, and Missile Tracking should remain the same. They will, however, execute more frequently because of the shorter accumulation interval. The results of this test are presented in Figures 4-6.

Examination of the results in these figures shows that the model has responded properly to the longer radar block. The decrease in the accumulation interval occurs as expected (Figure 4) and the model results are very close to the measured data. The pulse allocation time has also decreased as expected and is very close to the measured results. (Unfortunately the pulse allocation time for this test is close to the Kalman Filter time and thus the plot of these two sets of curves overlap).

The model values for Track Initiation and Missile Tracking remain very close (Figures 5 and 6 respectively) as expected.

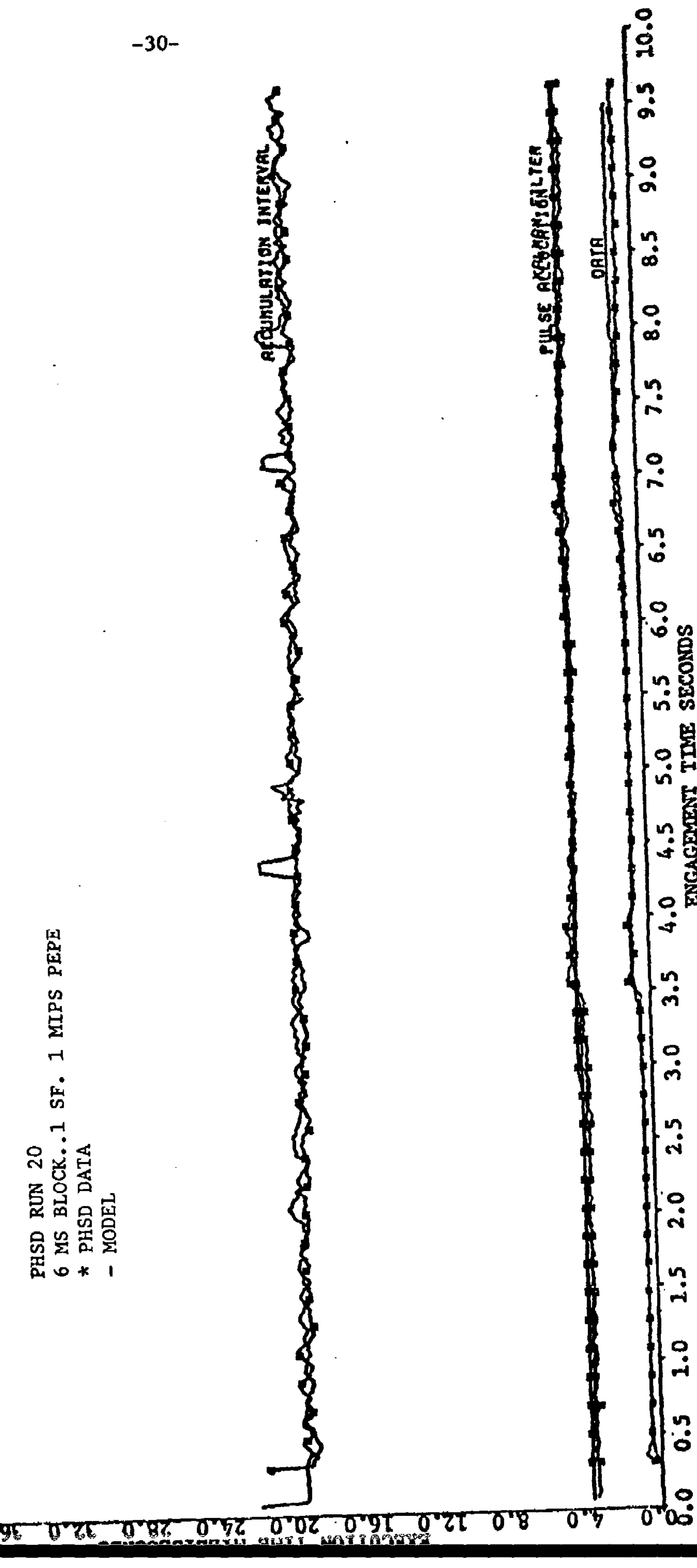
PHSD RUN 20
6 MS BLOCK..1 SF. 1 MIPS PEPE
* PHSD DATA
- MODEL
ACCUMULATION INTERVAL
DATA
ENGAGEMENT TIME SECONDS
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
0.0 4.0 8.0 12.0 16.0 20.0 24.0 28.0 32.0 36.0 40.0 44.0 48.0

FIGURE 4

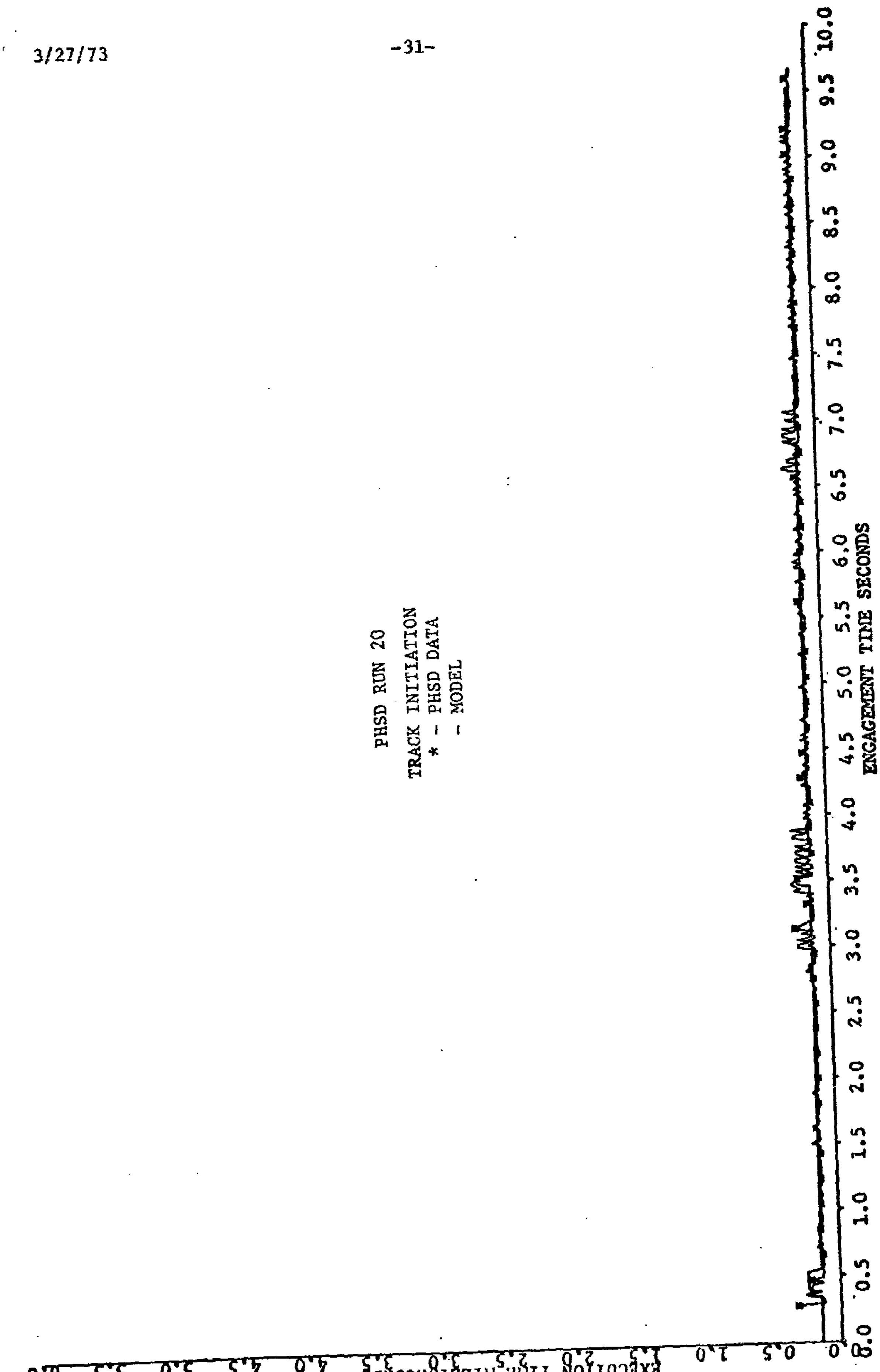
PHSD RUN 20
TRACK INITIATION
* - PHSD DATA
- MODEL
ENGAGEMENT TIME SECONDS
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
EXECUTION TIME MILLISECONDS
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

FIGURE 5

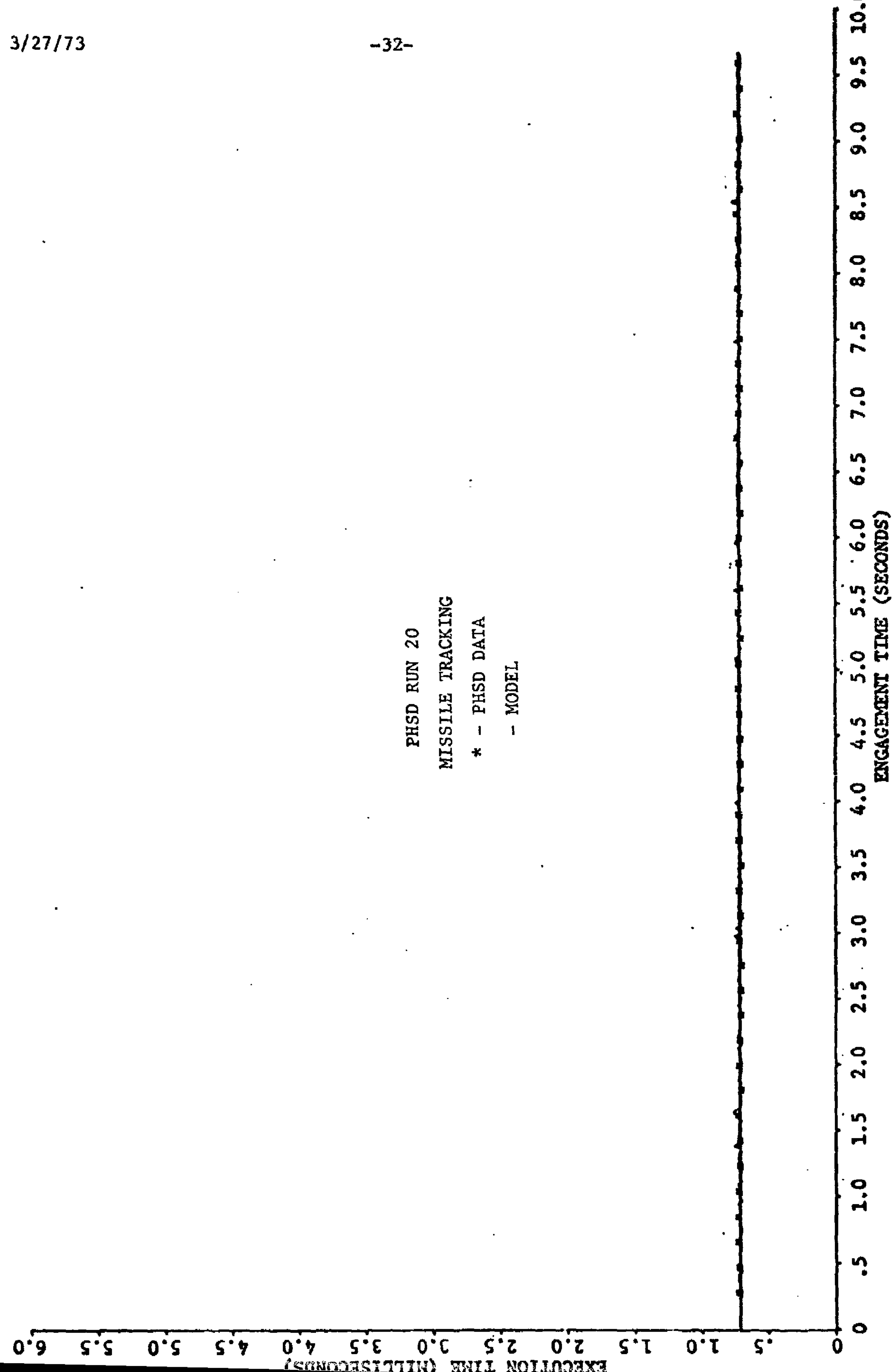
PHSD RUN 20
MISSILE TRACKING
* - PHSD DATA
- MODEL
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
ENGAGEMENT TIME (SECONDS)
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
EXECUTION TIME (MILLISECONDS)

FIGURE 6

3.3.3 Test 18 (PHSD Run 33)

Test 18 corresponds to PHSD Run 33. All System Parameters in this test are the same as those in Test 16 except the PEPE speed has been decreased from 1 mip to 0.5 mip. This change should cause a slight decrease in the accumulation interval and an increase in the execution (run) time of the parallel programs. The results of this test are presented in Figures 7-9. These results show that since the model results are close to the measured data, the model responds properly to the perturbation. The apparent difference between the model results and the PHSD data for the pulse allocation program is not the result of an improper calibration but rather a measurement error in the PHSD data for run 33.

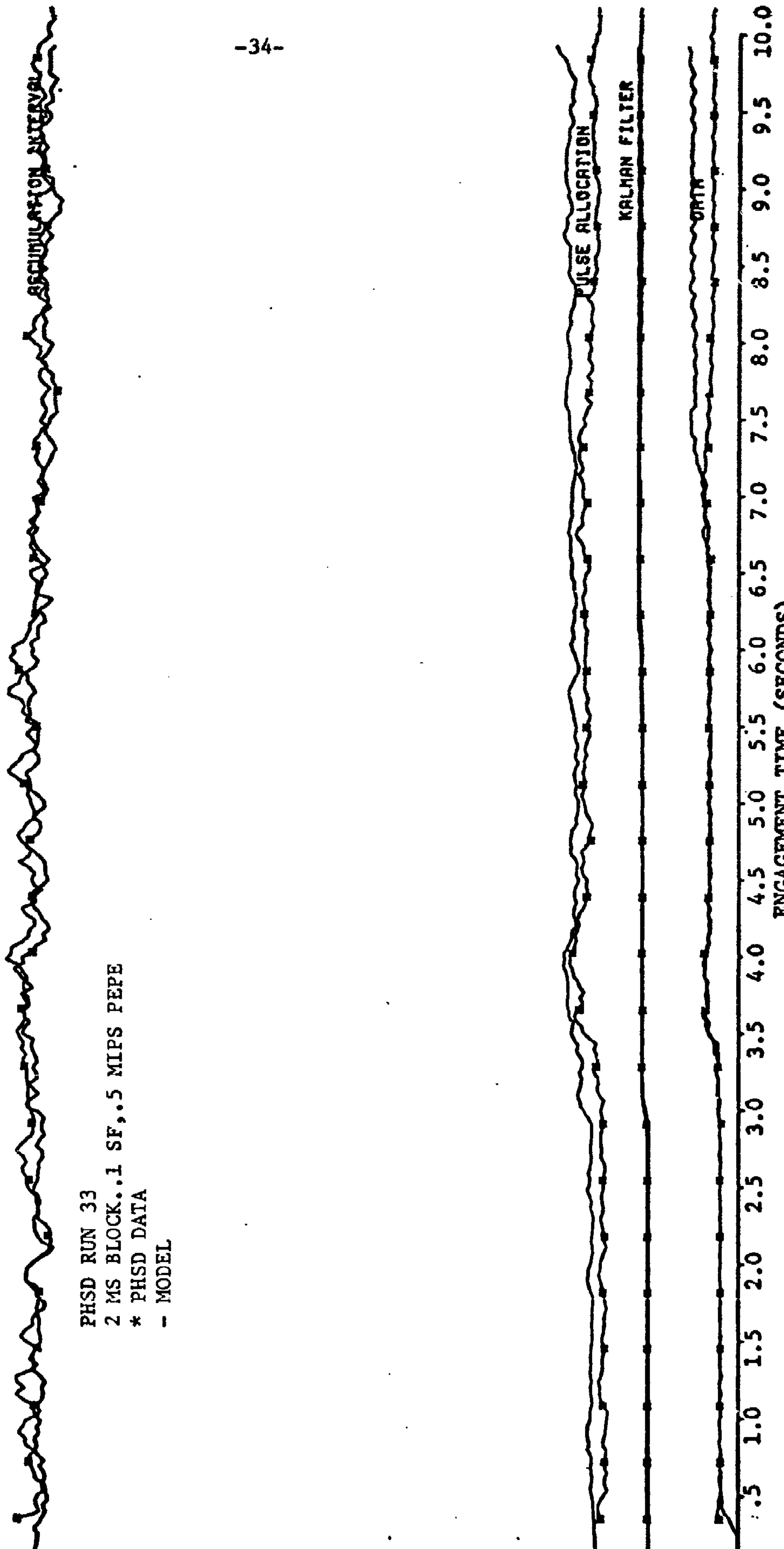
PHSD RUN 33
2 MS BLOCK..1 SF,.5 MIPS PEPE
* PHSD DATA
- MODEL
ACCUMULATION INTERVAL
PULSE ALLOCATION
KALMAN FILTER
DATA
.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
ENGAGEMENT TIME (SECONDS)

FIGURE 7

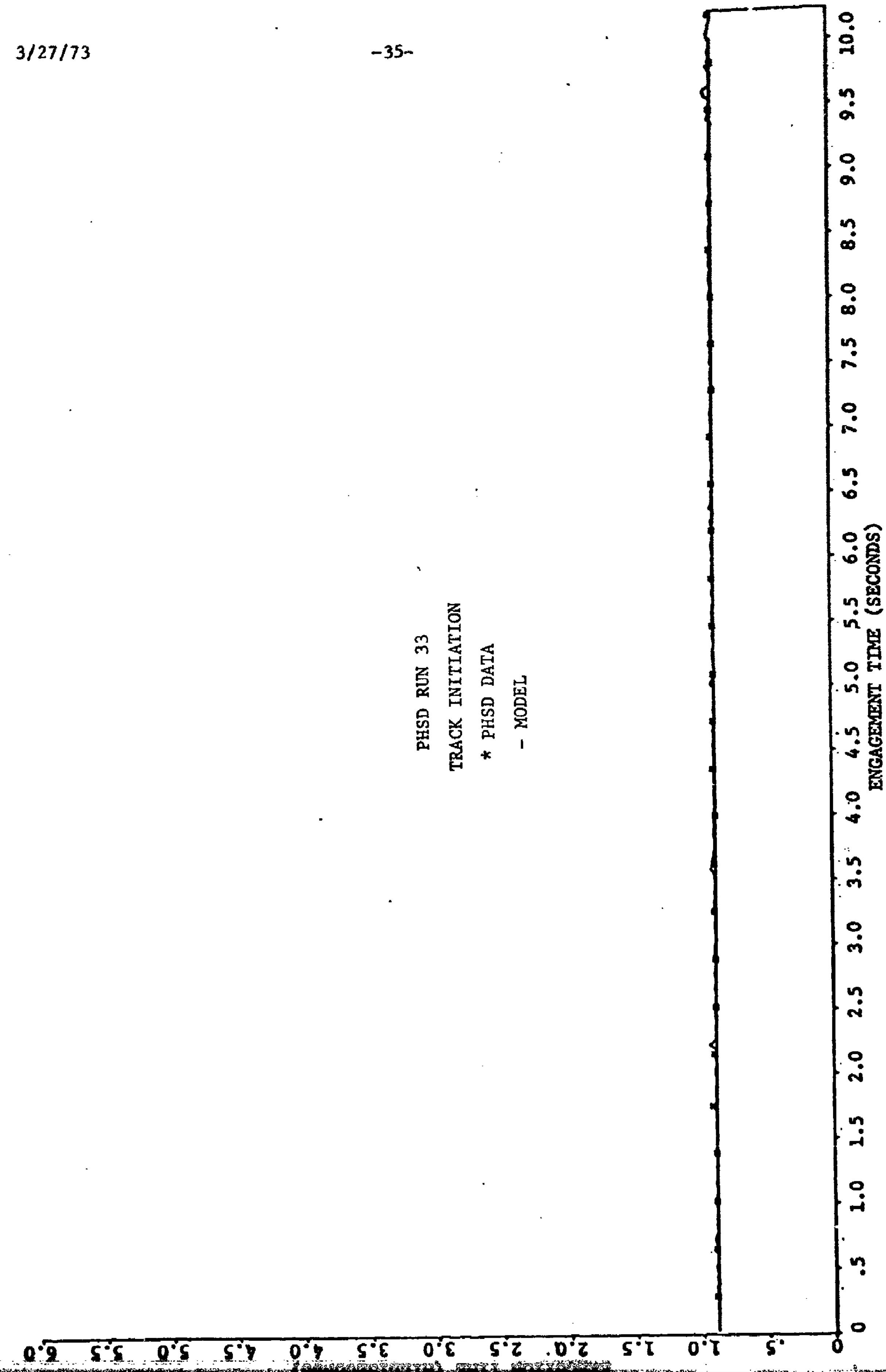
PHSD RUN 33
TRACK INITIATION
* PHSD DATA
- MODEL
ENGAGEMENT TIME (SECONDS)
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

FIGURE 8

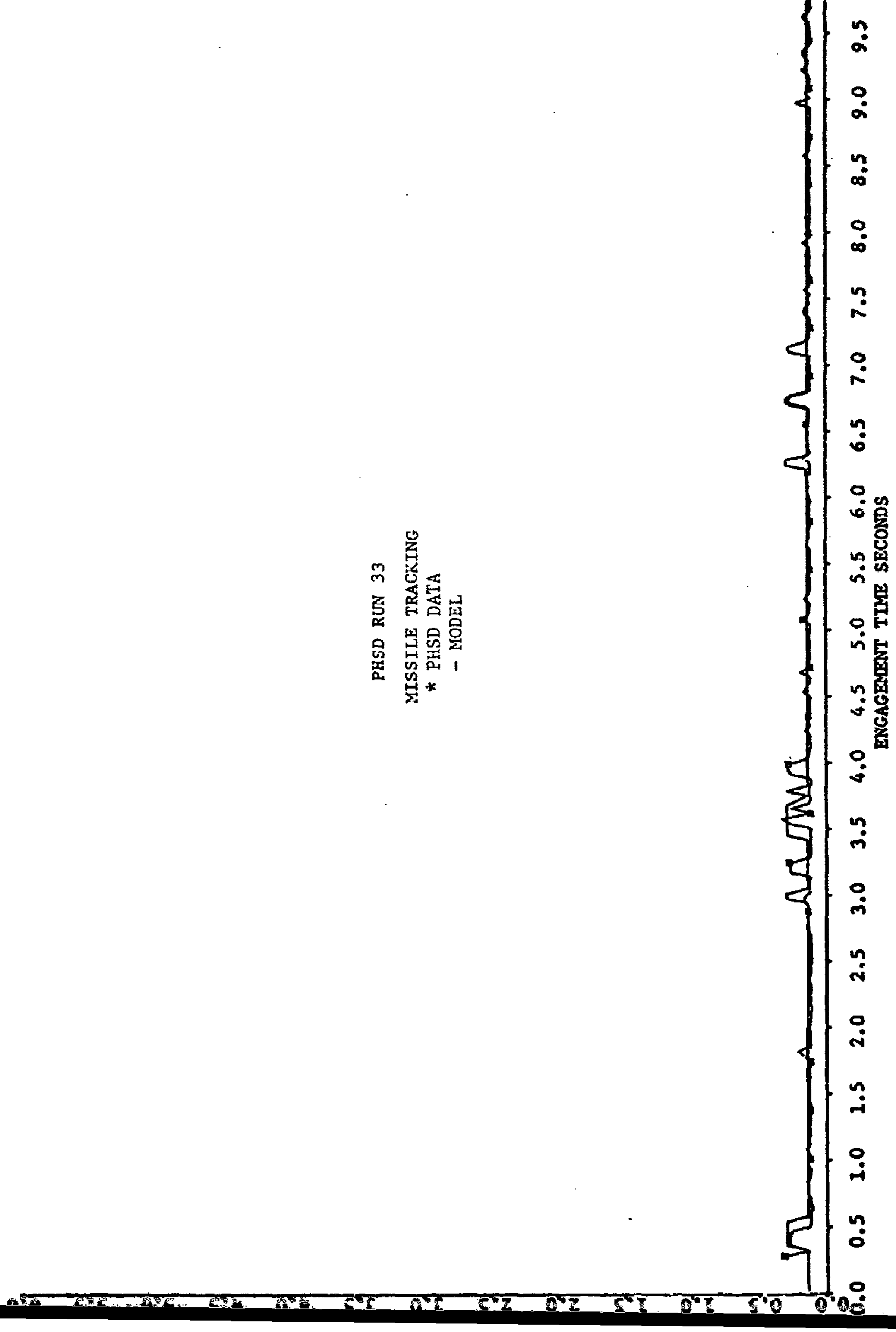
PHSD RUN 33
MISSILE TRACKING
* PHSD DATA
- MODEL
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
ENGAGEMENT TIME SECONDS

FIGURE 9

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PEPE FUNCTIONAL SIMULATION

SYSTEM VERIFICATION MODEL

DETAILED TEST PLANS

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1.0 INTRODUCTION

The PEPE simulation project has the responsibility of validating the design of the MSI PEPE by functional simulation. Design validation will be achieved by showing that the performance characteristics of the MSI PEPE are superior to those of the IC design in the PHSD tactical situation. Performance characteristics of the MSI PEPE will be obtained from a functional simulation model of the PHSD tactical process operating on the MSI PEPE/CDC 7600/RIC equipment configuration. The model is called the System Verification Model (SVM).*

The approach used for the development of the SVM model is to (1) construct a (functional) simulation model of the PHSD tactical process operating on the PEPE equipment configuration used for the PHSD demonstrations, (2) calibrate the above model so that the performance characteristics of this model are the same (within limits) as that of the PHSD demonstration system and (3) perturb (modify) the model to reflect the operation of the PHSD tactical process on the MSI PEPE/CDC 7600/RIC equipment configuration.

The purpose of this document is to (1) specify the tests that must be performed and the criteria that must be satisfied to show that the PHSD tactical process is properly implemented on the MSI PEPE/CDC 7600/RIC equipment configuration and (2) specify the design validation tests for the MSI PEPE.

1.1 RELATED DOCUMENTS

The detailed test plans and the results of the PEPE functional simulations are presented in a set of four related documents. These documents are:

PEPE Functional Simulation Calibration Model - Detailed Test Plans	TM-HU-048/500/00

* The SVM model has also been called the Version One Functional Simulation Model.

PEPE Functional Simulation Calibration Model - Calibration Test Results	TM-HU-048/501/00
PEPE Functional Simulation System Verification Model - Detailed Test Plans	TM-HU-048/502/00
PEPE Functional Simulation System Verification Model - SVM Test Results	TM-HU-048/503/00

2.0 OBJECTIVE

The test plan objective for the System Verification Model is to design a set of tests that can be used to determine whether or not the MSI PEPE performs satisfactorily when executing the PHSD tactical process on the MSI PEPE/CDC 7600/RIC equipment configuration.

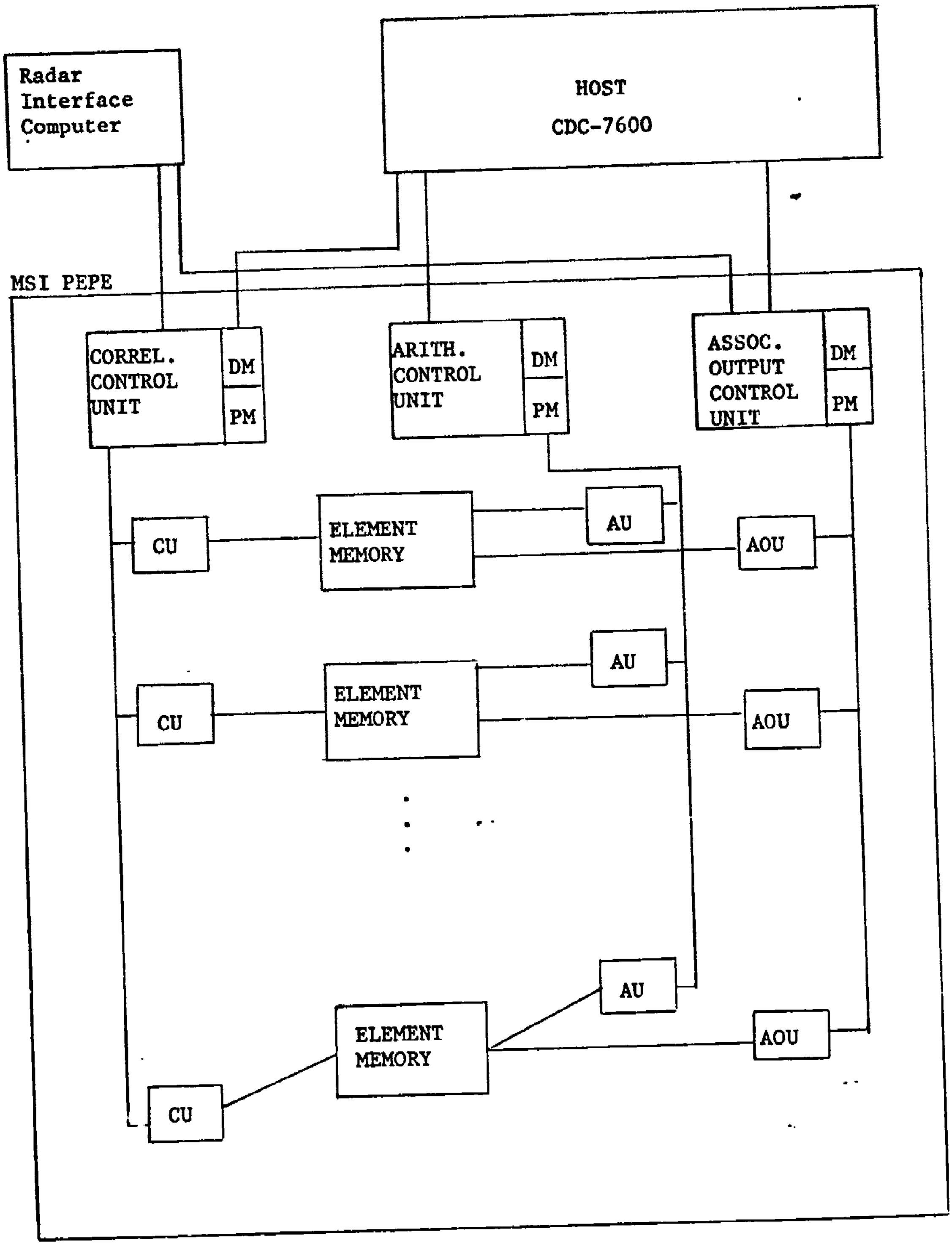
3.0 SCOPE OF THE SVM TESTS

The tests specified in this document are designed to determine (1) whether or not the PHSD tactical process is properly implemented in the System Verification Model and (2) whether or not the MSI PEPE performs satisfactorily when executing the PHSD tactical process on the MSI PEPE/CDC 7600/RIC equipment configuration.

The tests specified in this document will not evaluate all intermediate steps in the evaluation of the MSI design. Thus, for example, there will not be a test devoted to the "instruction streaming" versus "no instruction streaming" issue. Such tests are possible, however, not with present resources.

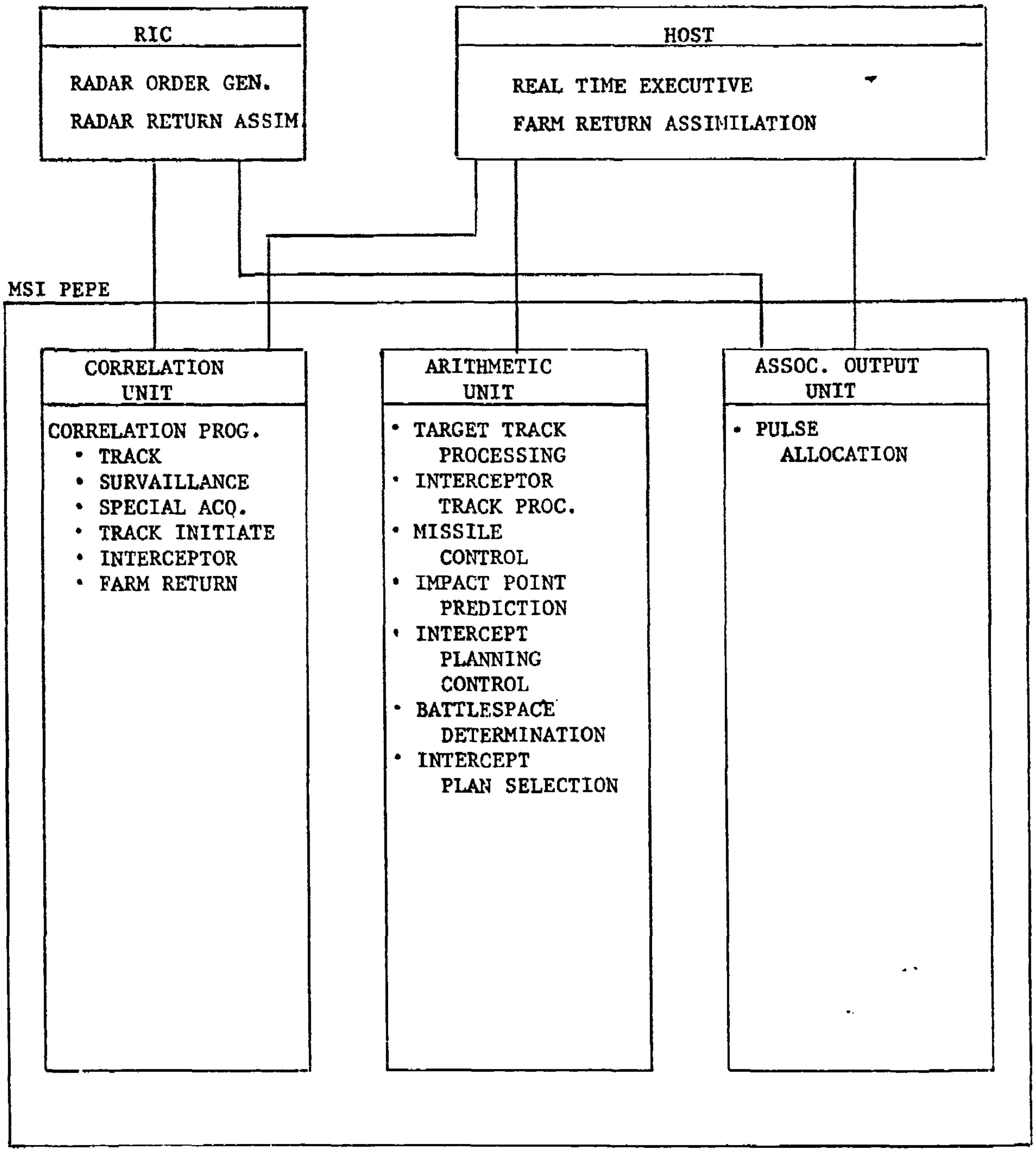
4.0 SYSTEM VERIFICATION MODEL

The System Verification Model is a high level functional simulation of the PHSD tactical process operating on the MSI PEPE/CDC 7600/RIC equipment configuration (figure 1). The threat model, radar model and the interceptor model are the same as those used for the Calibration Model. The SVM software configuration is shown in figure 2. This figure shows how the PHSD tactical process is mapped onto the MSI PEPE equipment configuration for the SVM model.



SVM HARDWARE CONFIGURATION

FIGURE 1



MAPPING OF PHSD PRCCESS ONTO THE
SVM HARDWARE CONFIGURATION

Figure 2

5.0 SYSTEM VERIFICATION MODEL TESTS

Two sets of tests have been developed for the System Verification Model; BMD Effectiveness tests and Hardware Validation tests.

The BMD effectiveness tests (Type I) are designed to check the processing logic of the model. These tests are computer independent and thus the same set of BMD effectiveness tests used for the Calibration Model can also be used for the System Verification Model.

The Hardware Validation tests (Type IV)* are designed to determine whether or not the design of the MSI PEPE is such that the performance of the MSI PEPE is satisfactory when executing the PHSD tactical process in the MSI PEPE/CDC 7600/RIC equipment configuration.

5.1 BMD EFFECTIVENESS TESTS (TYPE I)

The BMD effectiveness tests for the System Verification Model are the same as those for the Calibration Model. They have, however, been included in this document in order to make it complete and self contained.

The BMD effectiveness tests consist of a set of tests which exercise all significant branches of the PHSD engagement logic. Eight test scenarios have been designed. They range in complexity from a single non-radar threat to a 17 object threat with radar attackers non-radar threats and non-threatening. The Type I tests are similar to the GRC scenarios used for PHSD testing. The major difference being the fact that the calibration model uses a 2-dimensional radar and a simple atmospheric model.

5.1.1 Acceptance Criterion

The acceptance criterion for the BMD effectiveness test is the function history (obtained from the simulator) for each object. Each test must be within the nominal specified functional history for each object where

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*These tests are labeled Type IV rather than Type II to avoid any possible confusion with the Type II and Type IV test for the Calibration Model.

the functional history is the engagement time (expressed as seconds from RV launch) of the following events for each object:

1. Initial search hit
2. Track initiation
3. Early track
4. Precision track
5. MAR sent
6. LCS sent
7. Missile in track
8. Missile failure detected
9. Missile burst confirmed
10. Special acquisition
11. Target track dropped (final radar acquisition)

See TM-HU-048/500/00 for a more thorough discussion of BMD function histories.

5.1.2 Type I Tests - General Description

A general description of the Type I tests follows. A summary of the BMD effectiveness tests including a list of the PHSD functions exercised by each test is presented in Table 5.1.

Test 1 (Reference GRC Scenario 11)

The attack plan for test 1 consists of a single RV being classified as a non-radar threat (NRT). The objective of the test is to show that the simulator is able to detect and track an object, and plan and execute its intercept. No missile failures are allowed in test 1. All tracking functions, with the exception of Special Acquisition and Track-While-Scan, are exercised. All interceptor functions, except kill assessment and post-LCS failure replacements, are exercised.

Test 2 (Reference GRC Scenario 11)

Same as test 1 except that a pre-launch missile failure occurs on the first missile. The objective of the test is to show that the missile is replaced and the interception is completed.

VERIFICATION MODEL

BMD EFFECTIVENESS TESTS

TEST NO.	GRC SC#	NO. OBJECTS	THREAT STATUS	MISSILE FAILURE Y/N	MISSILE FAILURE TYPE	FUNCTIONS TESTED: Radar Ret. Assimilation	Surveillance Proc. Ex. TWS	TWS	Special Acq.	Target Trk. Proc.	Int. Plan CTL ex. KILLA, post L.F.R.	Kill Assmnt.	Post LCS Replacement	Battle Space	Inter. Plan Selection	Farm Comm.	Missile CTL	Inter. Trk. Processing	Pulse Alloc.	Radar Order Gen.
1	11	1	NRT	N		X	X			X	X			X	X	X	X	X	X	X
2	11	1	NRT	Y	Pre-Launch	X	X			X	X			X	X	X	X	X	X	X
3	11	1	NRT	Y	Post-Launch	X	X			X	X			X	X	X	X	X	X	X
4	11	1	RT	Y	Post-Launch	X	X			X	X	X	X	X	X	X	X	X	X	X
5	12	10	RT,NRT	N		X	X		X	X	X	X		X	X	X	X	X	X	X
6	12	10	RT,NRT	Y	Post-Launch	X	X		X	X	X	X	X	X	X	X	X	X	X	X
7	13	17	RT,NRT,NT	N		X	X	X	X	X	X	X		X	X	X	X	X	X	X
8	13	17	RT,NRT,NT	Y	Post-Launch	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 5.1

Test 3 (Reference GRC Scenario 11)

Same as test 1 except that a post-launch missile failure occurs. A second missile is not replanned since the RV is classified as a non-radar threat. Instead the object is dropped from track after the failure is detected.

Test 4 (Reference GRC Scenario 11)

The attack plan for this test is similar to that of test 1 except the RV is classified as a radar threat (rather than a non-radar threat). A post-launch missile failure occurs during this test. The objective of this test is to show that (after detection of the first missile failure) a second intercept is planned and successfully implemented. All functions except Special Acquisition and Track-While-Scan are exercised during this test.

Test 5 (Reference GRC Scenario 12)

The attack plan for this test consists of 10 RV's, some being classified as non-radar threats and some as radar threats. No missile failures occur during this test. The radar cross section (RCS) of two of the objects go to zero for 1-2 seconds thereby exercising the Special Acquisition branch of the PHSD logic. The objective of this test is to show that multiple objects can be detected, tracked and intercepted. The Track-While-Scan (TWS) and post-LCS (Launch Command Sequence), replacement functions are not exercised during this test.

Test 6 (Reference GRC Scenario 12)

This test is the same as test 5 except that a post-launch missile failure occurs on a radar attacker. A second shot should be replanned and successfully executed.

Test 7 (Reference GRC Scenario 13)

The threat for test 7 consists of 12 RV's, one tank and four tank fragments. The one tank and four tank fragments will be classified as non-radar threats. One of the RV's is also classified as a non-radar threat. Therefore, six objects will exercise the Track-While-Scan (TWS) branch of the PHSD logic. The Special Acquisition logic will also be exercised, since the radar cross section (RCS)of two of the RV's will go to zero for about 2 seconds. No missile failures will occur during this test.

Test 8 (Reference GRC Scenario 13)

This test is the same as 7 except that post-launch missile failures occur. Two failures occur on missiles assigned to a radar threat and one on a missile assigned to a non-radar threat. A second interception should be planned and executed against the radar attackers. The non-radar threat should be dropped after detection of the failure. This test exercises all PHSD functions.

5.1.3 Equipment Configuration

The equipment configuration required for the Type I tests is the MSI PEPE/ CDC-7600/RIC equipment configuration shown in Figure 1 of this document.

5.1.4 Search Volume

The search volume associated with the SVM Model is assumed to consist of three search sectors and that the scan rate for each sector can be specified by the test planner. The scan rates chosen for the BMD effectiveness tests are as follows:

Search Sector	Time Per Scan
1	3.85 sec.
2	2.2 sec.
3	1.65 sec.

It should also be noted that all function history calculations are based on the assumption that the minimum and maximum ranges can be specified for each search sector.

5.1.5 Tracking Rate

All objects are assumed to be tracked at 20 Hertz (targets and interceptors).

5.1.6 Test Sequence

There are no specific requirements for sequencing the Type I tests. Test 8, the most complex test, exercises all required PHSD logic branches. Therefore, satisfactory completion of test 8 obviates the other seven tests.

5.1.7 Type I Tests - Detailed Test Plan

A detailed description of the Type I tests plans for the SVM Model follows. The acceptance criteria (i.e., nominal functional history) is included for each test.

5.1.7.1 Test 1 (Reference GRC Scenario 11). The attack plan for test 1 consists of a single RV entering search sector 3 at beam position 300. The RV is classified as a non-radar threat (NRT). The RV enters the volume at 2985 seconds and its range at entry is 92 km. The RV's speed is 7100m/s throughout the exercise.

The minimum and maximum search ranges for search sector 3 are:

Minimum range	66 km.
Maximum range	92 km.

No missile failures occurred during this test. The interceptor speed is 2360m/s.

The nominal function history for test 1 is presented in Table 5.2.

ENGAGEMENT TIME (SEC)	FNCTION
2985.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2995.54 - 2996.35	Missile burst confirmed
2995.54 - 2996.90	Target track dropped

Function History

Table 5.2

5.1.7.2 Test 2 (Reference GRC Scenario 11). Same as test 1 except that a prelaunch missile failure occurs on the first missile assigned to the RV. A second missile is assigned and the mission proceeds without any further failures.

The functional history for test 2 is presented in Table 5.3. Note that it is the same as that for test 1.

ENGAGEMENT TIME (SEC)	FUNCTION
2935.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early Track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2995.54 - 2996.35	Missile burst confirmed
2995.54 - 2996.90	Target track dropped

Function History

Table 5.3

5.1.7.3 Test 3 (Reference GRC Scenario 11). This test is basically the same as test 1. The only difference being that a failure occurs in the first interceptor assigned to the target at 2.75 seconds after launch. A second interceptor is not assigned to this target since it is classified as a non-radar threat (NRT). The object should be dropped from track after the failure has been detected.

The nominal function history for test 3 is presented in Table 5.4.

ENGAGEMENT TIME (Sec)	FUNCTION
2985.00 - 2986.65	Initial search/verify hits
2985.02 - 2986.67	Track initiation
2985.12 - 2986.77	Early track
2987.52 - 2989.17	Precision track
2987.52 - 2990.27	MAR sent
2987.67 - 2990.52	LCS sent
2989.72 - 2993.57	Missile track acquired
2990.92 - 2994.32	Missile failure detected
2990.92 - 2994.87	Target track dropped

Function History
Table 5.4

5.1.7.4 Test 4 (Reference GRC Scenario 11). The attack plan for this test consists of a single RV entering search sector 3 at beam position 300. The RV is classified as a radar threat (RT). The first interceptor assigned to this target has a post launch failure which occurs at 2.75 seconds after launch. A second interception is to be planned and executed.

The object enters the search volume at 2981 seconds. Its range at entry is 120.4 km. The speed of the target is 7100 m/s.

The search sector range gates for this test are:

Minimum range	94 km
Maximum range	121 km

The interceptor speed is 2360 m/s.

The nominal function history for test 4 is presented in Table 5.5.

ENGAGEMENT TIME (Sec)	FUNCTION
2981.00 - 2982.65	Initial search/verify hits
2981.02 - 2982.67	Track initiation
2981.12 - 2982.77	Early track
2983.52 - 2985.17	Precision track
2983.52 - 2986.27	MAR sent
2983.67 - 2986.52	LCS sent
2985.72 - 2989.57	Missile track acquired
2986.92 - 2990.32	Missile failure detected
2986.92 - 2990.92	MAR sent
2987.07 - 2992.12	LCS sent
2989.12 - 2994.32	Missile track acquired
2995.32 - 2996.75	Missile brust confirmed
2995.32 - 2997.30	Target track dropped

Function History
Table 5.5

5.1.7.5 Test 5 (Reference GRC Scenario 12). The attack plan for test 5 consists of 10 RV's entering search sectors 1 and 3. Six of the RV's are classified as radar threats (RT) and four as non-radar threats (NRT). The radar cross section (RCS) on two of the objects goes to zero for about 2 seconds at the RCS for objects 3 and 4 is zero during the time intervals 2973.50 - 2975.40 seconds and 2981.00 - 2983 seconds respectively. Both of these targets should cause the Special Acquisition logic to be exercised.

The minimum and maximum search ranges for search sectors 1 and 3 for this test are:

Search Sector	Search Range (km.) Minimum	Maximum
1	105	135
3	66	98

All targets have the same speed - 7100 m/s.

All interceptors have the same speed - 2360 m/s.

No interceptor failures occur during this test.

The threat status, search sector entered, time of entry into search volume, beam position at entry and range at entry for each object in the test follows:

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	TIME OF ENTRY	BEAM POSITION	RANGE AT ENTRY
1	RT	1	2967	50	135
2	RT	1	2971	75	135
3	RT	1	2967	100	135
4	RT	1	2971	125	135
5	RT	1	2967	150	135
6	RT	1	2971	175	135
7	NRT	3	2974	300	98
8	NRT	3	2974	400	98
9	NRT	1	2977	300	135
10	NRT	1	2977	350	135

The anticipated function history for each object is presented in Table 5.6

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped
	--continued--

FUNCTION HISTORY

Table 5.6

Table 5.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 2	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 3	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.65 - 2973.75	Special acquisition
2975.40 - 2975.55	Precision track or track initiate
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped.

-- continued --

Table 5.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 4	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2981.15 - 2981.25	Special acquisition
2983.00 - 2983.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 5	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

— continued —

Table 5.6 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 7	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped
Object No. 8	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped

— continued —

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped
Object No. 10	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped

5.1.7.6 Test 6 (Reference GRC Scenario 12). This test is basically the same as test 5 except for a post launch failure on three interceptors. The targets enter exactly the same way as in test 5; the same entry point, same ranges and the same times. The target threat status is the same as in test 5. The targets enter at the same speed.

The radar cross section (RCS) for objects 3 and 4 goes to zero for the same period of time.

The only difference is that in test 6 a post launch missile failure occurs in the first missile assigned to objects 1, 2, and 7. The missile failure

time for each object is:

Object	Failure after Launch
1	3.5 sec.
2	3.0 sec.
7	2.75 sec.

A second interception should be planned and executed against objects 1 and 2 since they are radar attackers. Object 7 should be dropped from track after the missile failure has been detected.

The interceptor speeds for test 6 are the same as those for test 5.

The function history for each object in test 6 is presented in Table 5.7.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.67 - 2979.95	Missile failure detected
2973.67 - 2980.55	MAR sent
2973.82 - 2981.75	LCS sent
2975.87 - 2983.95	Missile track acquired
2983.12 - 2985.20	Missile burst confirmed
2983.12 - 2985.75	Target track dropped
	-- continued --

Function History

Table 5.7

Table 5.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 2	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2977.17 - 2983.45	Missile failure detected
2977.17 - 2984.05	MAR sent
2977.32 - 2985.25	LCS sent
2979.37 - 2987.45	Missile track acquired
2986.99 - 2989.18	Missile burst confirmed
2986.99 - 2989.73	Target track dropped
Object No. 3	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2973.65 - 2973.75	Special acquisition
2975.40 - 2975.55	Precision track or track initiate
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

— continued —

Table 5.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 4	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2981.15 - 2981.25	Special acquisition
2983.00 - 2983.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 5	
2967.00 - 2970.58	Initial search/verify hits
2967.02 - 2970.60	Track initiation
2967.12 - 2970.70	Early track
2969.52 - 2973.10	Precision track
2969.52 - 2974.20	MAR sent
2969.67 - 2975.40	LCS sent
2971.72 - 2977.60	Missile track acquired
2982.08 - 2983.62	Missile burst confirmed
2982.08 - 2984.17	Target track dropped

-- continued --

Table 5.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped
Object No. 7	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2979.82 - 2984.27	Missile failure detected
2979.82 - 2984.82	Target track dropped
Object No. 8	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.17 - 2986.23	Missile burst confirmed
2985.17 - 2986.78	Target track dropped

— continued —

Table 5.7 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped
Object No. 10	
2977.00 - 2980.58	Initial search/verify hits
2977.02 - 2980.60	Track initiation
2977.12 - 2980.70	Early track
2979.52 - 2983.10	Precision track
2979.52 - 2984.20	MAR sent
2979.67 - 2985.40	LCS sent
2981.72 - 2987.60	Missile track acquired
2992.08 - 2993.62	Missile burst confirmed
2992.08 - 2994.17	Target track dropped

5.1.7.7 Test 7 (Reference GRC Scenario 13). The attack plan for test 7 consists of 17 objects; 3 radar threats (RT), 8 non-radar threats (NRT), and 6 non-threatening objects (NT). The objects enter all three sectors of the search volume. The entry characteristics of each object follows:

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	ENTRY TIME	BEAM POSITION	ENTRY RANGE
1	NRT	3	2982	100	98
2	RT	1	2969	50	135
3	NRT	2	2974	20	118
4	NRT	2	2974	40	115

OBJECT	THREAT STATUS	SEARCH SECTOR ENTERED	ENTRY TIME	BEAM POSITION	ENTRY RANGE
5	NRT	1	2970	200	135
6	NT	2	2974	60	125
7	NT	2	2973	80	125
8	NT	2	2975	100	125
9	RT	1	2971	250	135
10	NRT	2	2973	120	120
11	RT	2	2973	140	119
12	NRT	2	2974	160	123
13	NT	2	2978	180	115
14	NT	3	2975	200	108
15	NRT	3	2974	300	104
16	NT	2	2973	200	125
17	NRT	2	2975	220	120

The entry speed for all objects is the same - 7100 m/s.

The minimum and maximum ranges for each search sector for test 7 are:

	Range (km)	
Search Sector	Minimum	Maximum
1	105.	135
2	85	125
3	75	110

Notice that during this test, the objects do not always enter at the maximum range of the search sector. The reason for doing this is to control the amount of time that each object spends in the search volume.

The radar cross section (RCS) for object 9 is zero during the interval 2980.00 - 2982.00 seconds. This object should exercise the Special Acquisition path of the tactical logic.

Objects 6, 7, 8, 13, 14, and 16 are non-threatening objects and should be placed in Track While Scan. They should be dropped from track after leaving the search volume.

No interceptor failures occur in this test. All interceptors fly at 2360 m/s.

The function history for each object is presented in Table 5.8.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2982.00 - 2983.65	Initial search/verify hits
2982.02 - 2983.67	Track initiation
2982.12 - 2983.77	Early track
2984.52 - 2986.17	Precision track
2984.52 - 2987.27	MAR sent
2984.67 - 2988.47	LCS sent
2986.72 - 2990.67	Missile track acquired
2993.17 - 2994.24	Missile burst confirmed
2993.17 - 2994.79	Target track dropped
Object No. 2	
2969.00 - 2972.58	Initial search/verify hits
2969.02 - 2972.60	Track initiation
2969.12 - 2972.70	Early track
2971.52 - 2975.10	Precision track
2971.52 - 2976.20	MAR sent
2971.67 - 2977.40	LCS sent
2973.72 - 2979.60	Missile track acquired
2984.08 - 2985.62	Missile burst confirmed
2984.08 - 2986.17	Target track dropped

—continued—

Function History

Table 5.8

Table 5.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 3	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.12	Missile track acquired
2986.23 - 2988.92	Missile burst confirmed
2986.23 - 2989.47	Target track dropped
Object No. 4	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.97 - 2988.61	Missile burst confirmed
2986.97 - 2989.16	Target track dropped
Object No. 5	
2970.00 - 2973.58	Initial search/verify hits
2970.02 - 2973.60	Track initiation
2970.12 - 2973.70	Early track
2972.52 - 2976.10	Precision track
2972.52 - 2977.20	MAR sent
2972.67 - 2978.40	LCS sent
2974.72 - 2980.60	Missile track acquired
2985.08 - 2986.62	Missile burst confirmed
2985.08 - 2987.17	Target track dropped

— continued —

Table 5.8 (Continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Track while scan
2979.63 - 2981.83	Drop track while scan
Object No. 7	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 8	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Track while scan
2980.63 - 2982.83	Drop track while scan
Object No. 9	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2980.15 - 2980.25	Special acquisition
2982.00 - 2982.15	Precision track or track initiate
2986.08 - 2987.62	Missile burst confirmed
2986.08 - 2988.17	Target track dropped

-- continued --

Table 5.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 10	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.60 - 2988.18	Missile burst confirmed
2986.60 - 2988.68	Target track dropped
Object No. 11	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.12	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.39 - 2988.03	Missile burst confirmed
2986.39 - 2988.58	Target track dropped
Object No. 12	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.55 - 2989.45	Missile burst confirmed
2986.55 - 2990.00	Target track dropped

— continued —

Table 5.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 13	
2978.00 - 2980.20	Initial search/verify hits
2978.02 - 2980.22	Track initiation
2978.12 - 2980.32	Early track
2980.52 - 2982.72	Track while scan
2982.23 - 2984.43	Drop track while scan
Object No. 14	
2975.00 - 2976.65	Initial search/verify hits
2975.02 - 2976.67	Track initiation
2975.12 - 2976.77	Early track
2977.52 - 2979.17	Track while scan
2980.65 - 2982.30	Drop track while scan
Object No. 15	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.81 - 2986.86	Missile burst confirmed
2985.81 - 2987.41	Target track dropped
Object No. 16	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan

-- continued --

Table 5.8 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 17	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Precision track
2977.52 - 2980.82	MAR sent
2977.67 - 2982.02	LCS sent
2979.72 - 2984.22	Missile track acquired
2987.55 - 2990.13	Missile burst confirmed
2987.55 - 2990.63	Target track dropped

5.1.7.8 Test 8 (Reference GRC Scenario 13). This test is exactly the same as test 7 except that three interceptors fail in flight. Two of the failures are against radar attackers and one against a non-radar threat. A second interception should be planned and executed against the radar attackers. The NRT object should be dropped from track as soon as the failure is detected.

The failures are associated with interceptors assigned to objects 2, 5, and 9. All failures occur at 2.75 seconds after launch.

Note: If everything works as expected, these failures should occur in the first three missiles launched with the first interceptor assigned to object 2, the second to object 5 and the third to object 9.

The RCS on object 9 goes to zero for the same period of time as in test 7.

The expected function history for each object is test 8 is presented in Table 5.9.

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 1	
2982.00 - 2983.65	Initial search/verify hits
2982.02 - 2983.67	Track initiation
2982.12 - 2983.77	Early track
2984.52 - 2986.17	Precision track
2984.52 - 2987.27	MAR sent
2984.67 - 2988.47	LCS sent
2986.72 - 2990.67	Missile track acquired
2993.17 - 2994.24	Missile burst confirmed
2993.17 - 2994.79	Target track dropped
Object No. 2	
2969.00 - 2972.58	Initial search/verify hits
2969.02 - 2972.60	Track initiation
2969.12 - 2972.70	Early track
2971.52 - 2975.10	Precision track
2971.52 - 2976.20	MAR sent
2971.67 - 2977.40	LCS sent
2973.72 - 2979.60	Missile track acquired
2974.92 - 2981.20	Missile failure detected
2974.92 - 2981.80	MAR sent
2975.07 - 2983.00	LCS sent
2977.12 - 2985.20	Missile in track
2984.93 - 2987.01	Missile burst confirmed
2984.93 - 2987.56	Target track dropped
	— continued —

Function History

Table 5.9

Table 5.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 3	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.23 - 2988.92	Missile burst confirmed
2986.23 - 2989.47	Target track dropped
Object No. 4	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.97 - 2988.61	Missile burst confirmed
2986.97 - 2989.16	Target track dropped
Object No. 5	
2970.00 - 2973.58	Initial search/verify hits
2970.02 - 2973.60	Track initiation
2970.12 - 2973.70	Early track
2972.52 - 2976.10	Precision track
2972.52 - 2977.20	MAR sent
2972.67 - 2978.40	LCS sent
2974.72 - 2980.60	Missile track acquired
2975.92 - 2982.20	Missile failure detected
2975.92 - 2982.75	Target track dropped

-- continued --

Table 5.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 6	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2976.32	Early track
2976.52 - 2978.72	Track while scan
2979.63 - 2981.83	Drop track while scan
Object No. 7	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 8	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Track while scan
2980.63 - 2982.83	Drop track while scan
Object No. 9	
2971.00 - 2974.58	Initial search/verify hits
2971.02 - 2974.60	Track initiation
2971.12 - 2974.70	Early track
2973.52 - 2977.10	Precision track
2973.52 - 2978.20	MAR sent
2973.67 - 2979.40	LCS sent
2975.72 - 2981.60	Missile track acquired
2976.92 - 2983.20	Missile failure detected
2976.92 - 2983.80	MAR sent
2977.07 - 2985.00	LCS sent
2979.12 - 2987.20	Missile in track

— continued —

Table 5.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 9 (cont'd.)	
2980.15 - 2980.25	Special acquisition
2982.00 - 2982.25	Precision track or track initiation
2986.93 - 2989.01	Missile burst confirmed
2986.93 - 2989.56	Target track dropped
Object No. 10	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.60 - 2988.18	Missile burst confirmed
2986.60 - 2988.68	Target track dropped
Object No. 11	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2973.32	Early track
2975.52 - 2977.72	Precision track
2975.52 - 2978.82	MAR sent
2975.67 - 2980.02	LCS sent
2977.72 - 2982.22	Missile track acquired
2986.39 - 2988.03	Missile burst confirmed
2986.39 - 2988.58	Target track dropped

— continued —

Table 5.9 (Continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 12	
2974.00 - 2976.20	Initial search/verify hits
2974.02 - 2976.22	Track initiation
2974.12 - 2977.32	Early track
2976.52 - 2978.72	Precision track
2976.52 - 2979.82	MAR sent
2976.67 - 2981.02	LCS sent
2978.72 - 2983.22	Missile track acquired
2986.55 - 2989.45	Missile burst confirmed
2986.55 - 2990.00	Target track dropped
Object No. 13	
2978.00 - 2980.20	Initial search/verify hits
2978.02 - 2980.22	Track initiation
2978.12 - 2980.32	Early track
2980.52 - 2982.72	Track while scan
2982.23 - 2984.43	Drop track while scan
Object No. 14	
2975.00 - 2976.65	Initial search/verify hits
2975.02 - 2976.67	Track initiation
2975.12 - 2976.77	Early track
2977.52 - 2979.17	Track while scan
2980.65 - 2982.30	Drop track while scan

-- continued --

Table 5.9 (continued)

ENGAGEMENT TIME (Sec)	FUNCTION
Object No. 15	
2974.00 - 2975.65	Initial search/verify hits
2974.02 - 2975.67	Track initiation
2974.12 - 2975.77	Early track
2976.52 - 2978.17	Precision track
2976.52 - 2979.27	MAR sent
2976.67 - 2980.47	LCS sent
2978.72 - 2982.67	Missile track acquired
2985.81 - 2986.86	Missile burst confirmed
2985.81 - 2987.41	Target track dropped
Object No. 16	
2973.00 - 2975.20	Initial search/verify hits
2973.02 - 2975.22	Track initiation
2973.12 - 2975.32	Early track
2975.52 - 2977.72	Track while scan
2978.63 - 2980.83	Drop track while scan
Object No. 17	
2975.00 - 2977.20	Initial search/verify hits
2975.02 - 2977.22	Track initiation
2975.12 - 2977.32	Early track
2977.52 - 2979.72	Precision track
2977.52 - 2980.82	MAR sent
2977.67 - 2982.02	LCS sent
2979.72 - 2984.22	Missile track acquired
2987.55 - 2990.13	Missile burst confirmed
2987.55 - 2990.63	Target track dropped

5.2 HARDWARE VALIDATION TESTS (TYPE IV)

The type IV tests are designed to determine whether or not the MSI PEPE performs satisfactorily when executing the PHSD tactical process on the MSI PEPE/CDC-7600/RIC equipment configuration. Satisfactory performance in this document means that the MSI PEPE performs better than the 1 mip IC PEPE. By better performance we mean that the program run time on the MSI PEPE should be less than or equal to those on the IC PEPE and not as sensitive to system load.

The Hardware Validation test is to be run on both the Calibration Model and the System Verification Model so that performance comparisons between the MSI and IC design can be made more easily.

Due to the limited resources available for the simulation effort only one Hardware Validation test has been specified at this time. Several others are possible and desirable, however, they must be deferred.

5.2.1 Hardware Validation Test 1.

The performance improvements that result from the MSI design are more readily apparent under fairly stressing situations, therefore, Hardware Validation test 1 will be a test with a large threat. The length of the scenario should be at least 20 seconds.

5.2.1.1 Threat. The threat for this test should be similar to that produced by GRC Scenario 14 in which several waves of objects penetrated the search volume simultaneously. The threat for this test should consist of at least 100 targets.

5.2.1.2 Interceptor. At least 100 interceptors should be available for this threat. The size of the Calibration Model Guidance ensemble should be increased to accommodate at least 150 interceptors.

5.2.1.3 Tracking Rate. All objects (targets and interceptors) shall be tracked at 20 Hertz.

5.2.1.4 Other System Parameters. The experimentalists are free to choose the values of all other system parameters, e.g., radar block size, however, they should remain the same for both equipment configurations.

5.2.1.5 Performance Measurements. The objective of the Hardware Validation test is to determine whether or not the MSI PEPE performs satisfactorily when the PHSD tactical process is executed on the MSI PEPE/CDC 7600/RIC equipment configuration. The exact meaning of "satisfactory performance" has not been specified and will depend primarily on judgement. Some guide lines, however, can be specified and they are:

a. Program run time on the MSI design should be faster than on the IC design for the same computational load.

b. Program run time on the MSI design should be less sensitive to apparent computational load than in the IC design (i.e., the slopes of program run times on the MSI design should be less than those on the IC design).

c. A single ensemble MSI configuration should be capable of handling the PHSD problem; that is, the single ensemble MSI configuration should not run out of data processing resources when executing the PHSD tactical process on the above equipment configuration.

To evaluate the MSI design the following performance data should be obtained from both the Calibration Model and the System Verification Model:

a. Target Track Processing - program run time
b. Pulse Allocation - program run time
c. Interceptor Track Processing - program run time
d. Missile Guidance and Control - program run time
e. PEPE accumulation interval

The above data should be recorded in such a manner that comparison of the results between the two models is relatively easy. One way of doing this is to record the program run times as a function of engagement time since the scenario is exactly the same for both models.

In addition to the above data, the following resource utilization information should be obtained from the System Verification Model:

a. Arithmetic Control Unit utilization

b. Associative Output Control Unit utilization

c. CDC-7600 Host utilization

Resource utilization should measure the amount of time that a given resource is "busy" during some time interval. The utilization information should be recorded as a function of engagement time and target load should be included as part of the data. The base time interval for the utilization measurements can be either the accumulation interval, or some other convenient interval such as 100 ms interval.

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PEPE FUNCTIONAL SIMULATION
SYSTEM VERIFICATION MODEL
ANALYSIS OF SVM TESTS

TABLE OF CONTENTS

1.0 INTRODUCTION

The System Verification Model is a functional simulation model of the PHSD tactical process operating on the MSI PEPE/CDC-7600/RIC equipment configuration. The System Verification Model (SVM) was created by perturbing the Calibration Model to reflect the architectual characteristics of the MSI PEPE and the CDC-7600 Host.

This document presents the results of the tests performed on the SVM. Two sets of tests were performed: BMD Effectiveness tests which check the logic of the tactical process, and Hardware Validation tests which determine whether or not the MSI PEPE performs satisfactory. The SVM test plans are presented in TM-HU-048/5-2/00.

1.1 RELATED DOCUMENTS

The detailed test plans and the results of the PEPE functional simulations are presented in a set of four related documents. These documents are:

PEPE Functional Simulation Calibration Model - Detailed Test Plans	TM-HU-048/500/00
PEPE Functional Simulation Calibration Model - Calibration Test Results	TM-HU-048/501/00
PEPE Functional Simulation System Verification Model - Detailed Test Plans	TM-HU-048/502/00
PEPE Functional Simulation System Verification Model - SVM Test Results	TM-HU-048/503/00

2.0 SUMMARY OF TEST RESULTS

The BMD Effectiveness tests performed on the SVM model are the same as those performed on the Calibration Model, since the tactical process is the same in both models. The SVM test results are the same as those obtained from the Calibration Model. This shows that the logic of the tactical process was preserved during the perturbation of the Calibration Model to the System Verification Model.

The results of the Hardware Validation test show that the MSI PEPE performs satisfactorily when executing the PHSD tactical logic on the MSI PEPE/CDC-7600/RIC equipment configuration. The results of this test show that (1) programs run faster on the MSI PEPE than on the IC design, (2) MSI program run times are less sensitive to system load, (3) Host overhead has been reduced significantly by placing logic control of the parallel process in PEPE, (4) both PHSD tracking and weapons functions can be successfully executed in a single MSI PEPE ensemble, (5) the MSI PEPE can successfully handle a PHSD problem containing more than 140 targets and 150 interceptors, and in addition the MSI PEPE has significant reserve capacity that can be used for larger threats and/or enhanced algorithms.

The detailed test results are presented in Section 3.

3.0 TEST RESULTS - SYSTEM VERIFICATION MODEL

3.1 BMD EFFECTIVENESS TEST RESULTS

The System Verification Model has satisfied all BMD Effectiveness test requirements and therefore the PHSD tactical process is said to be properly implemented on the MSI PEPE/CDC-7600/RIC equipment configuration. All test requirements were satisfied by a single test - Test 8. The results of this test are the same as the results on the Calibration Model. This shows that the engagement logic remained intact during the perturbation from the Calibration to the SVM model. The detailed results of this test is presented in Table 3.1. A more detailed discussion of this test is presented in Section 3.1 of TM-HU-048/501/00.

TABLE 3-1

TEST RESULTS - BMD EFFECTIVENSSS TESTS - SVM MODEL
TEST NUMBER 8

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 1		
2982.00 - 2983.65	2982.79	Initial search/verify hits
2982.02 - 2983.67	2982.79	Track initiation
2982.12 - 2983.77	2982.92	Early track
2984.52 - 2986.17	2985.51	Precision track
2984.52 - 2987.27	2985.80	MAR sent
2984.67 - 2988.47	2986.73	LCS sent
2986.72 - 2990.67	2989.57	Missile track acquired
2993.17 - 2994.24	2993.57	Missile burst confirmed
2993.17 - 2994.79	2993.82	Target track dropped
Object No. 2		
2969.00 - 2972.58	2969.31	Initial search/verify hits
2969.02 - 2972.60	2969.31	Track initiation
2969.12 - 2972.70	2969.42	Early track
2971.52 - 2975.10	2971.94	Precision track
2971.52 - 2976.20	2972.04	MAR sent
2971.67 - 2977.40	2972.94	LCS sent
2973.72 - 2979.60	2975.77	Missile track acquired
2974.92 - 2981.20	2976.49	Missile failure detected
2974.92 - 2981.80	2976.60	MAR sent
2975.07 - 2983.00	2977.49	LCS sent
2977.12 - 2985.20	2980.32	Missile in track
2984.93 - 2987.01	2985.28	Missile burst confirmed
2984.93 - 2987.56	2985.35	Target track dropped

-- continued --

Table 3.1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 3		
2974.00 - 2976.20	2974.73	Initial search/verify hits
2974.02 - 2976.22	2974.73	Track initiation
2974.12 - 2976.32	2974.84	Early track
2976.52 - 2978.72	2977.43	Precision track
2976.52 - 2979.82	2977.57	MAR sent
2976.67 - 2981.02	2978.50	LCS sent
2978.72 - 2983.22	2981.53	Missile track acquired
2986.23 - 2988.92	2987.43	Missile burst confirmed
2986.23 - 2989.47	2987.58	Target track dropped
Object No. 4		
2974.00 - 2976.20	2974.89	Initial search/verify hits
2974.02 - 2976.22	2974.89	Track initiation
2974.12 - 2976.32	2974.99	Early track
2976.52 - 2978.72	2977.54	Precision track
2976.52 - 2979.82	2977.83	MAR sent
2976.67 - 2981.02	2979.62	LCS sent
2978.72 - 2983.22	2982.45	Missile track acquired
2986.97 - 2988.61	2987.47	Missile burst confirmed
2986.97 - 2989.12	2987.58	Target track dropped
Object No. 5		
2970.00 - 2973.58	2970.18	Initial search/verify hits
2970.02 - 2973.60	2970.18	Track initiation
2970.12 - 2973.70	2970.28	Early track
2972.52 - 2976.o0	2972.87	Precision track
2972.52 - 2977.20	2973.05	MAR sent
2972.67 - 2978.40	2973.91	LCS sent
2974.72 - 2980.60	2976.74	Missile track acquired
2975.92 - 2982.20	2977.42	Missile failure detected
2975.92 - 2982.75	2977.60	Target track dropped

— continued —

Table 3.1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 6		
2974.00 - 2976.20	2975.05	Initial search/verify hits
2974.02 - 2976.22	2975.05	Track initiation
2974.12 - 2976.32	2975.18	Early track
2976.52 - 2978.72	2977.73	Track while scan
2979.63 - 2981.83	2977.77	Drop track while scan
Object No. 7		
2973.00 - 2975.20	2973.32	Initial search/verify hits
2973.02 - 2975.22	2973.32	Track initiation
2973.12 - 2975.32	2973.42	Early track
2975.52 - 2977.72	2975.97	Track while scan
2978.63 - 2980.83	2979.02	Drop track while scan
Object No. 8		
2975.00 - 2977.20	2975.37	Initial search/verify hits
2975.02 - 2977.22	2975.37	Track initiation
2975.12 - 2977.32	2975.48	Early track
2977.52 - 2979.72	2978.13	Track while scan
2980.63 - 2982.83	2980.70	Drop track while scan
Object No. 9		
2971.00 - 2974.58	2973.59	Initial search/verify hits
2971.02 - 2974.60	2973.59	Track initiation
2971.12 - 2974.70	2973.72	Early track
2973.52 - 2977.10	2976.27	Precision track
2973.52 - 2978.20	2976.60	MAR sent
2973.67 - 2979.40	2977.45	LCS sent
2975.72 - 2981.60	2980.28	Missile track acquired
2976.92 - 2983.20	2980.81	Missile failure detected
2976.92 - 2983.80	2981.07	MAR sent
2977.07 - 2985.00	2982.17	LCS sent
2979.12 - 2987.20	2985.02	Missile in track

— continued —

Table 3.1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 9 (cont'd.)		
2980.15 - 2980.25	2980.18	Special acquisition
2982.00 - 2982.25	2982.24	Precision track or track initiation
2986.93 - 2989.01	2988.06	Missile burst confirmed
2986.93 - 2989.56	2988.35	Target track dropped
Object No. 10		
2973.00 - 2975.20	2973.63	Initial search/verify hits
2973.02 - 2975.22	2973.63	Track initiation
2973.12 - 2975.32	2973.76	Early track
2975.52 - 2977.72	2976.31	Precision track
2975.52 - 2978.82	2976.60	MAR sent
2975.67 - 2980.02	2977.49	LCS sent
2977.72 - 2982.22	2980.31	Missile track acquired
2986.60 - 2988.18	2986.62	Missile burst confirmed
2986.60 - 2988.68	2986.84	Target track dropped
Object No. 11		
2973.00 - 2975.20	2973.79	Initial search/verify hits
2973.02 - 2975.22	2973.79	Track initiation
2973.12 - 2975.32	2973.91	Early track
2975.52 - 2977.72	2976.46	Precision track
2975.52 - 2978.82	2976.60	MAR sent
2975.67 - 2980.02	2977.42	LCS sent
2977.72 - 2982.22	2980.27	Missile track acquired
2986.39 - 2988.18	2986.51	Missile burst confirmed
2986.39 - 2988.58	2986.58	Target track dropped

— continued —

Table 3.1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 12		
2974.00 - 2976.20	2975.86	Initial search/verify hits
2974.02 - 2976.22	2975.86	Track initiation
2974.12 - 2977.32	2975.96	Early track
2976.52 - 2978.72	2978.58	Precision track
2976.52 - 2979.82	2978.90	MAR sent
2976.67 - 2981.02	2979.77	LCS sent
2978.72 - 2983.22	2982.79	Missile track acquired
2986.55 - 2989.45	2988.43	Missile burst confirmed
2986.55 - 2990.00	2988.57	Target track dropped
Object No. 13		
2978.00 - 2980.20	2979.81	Initial search/verify hits
2978.02 - 2980.22	2979.81	Track initiation
2978.12 - 2980.32	2979.93	Early track
2980.52 - 2982.72	2982.52	Track while scan
2982.23 - 2984.43	2982.62	Drop track while scan
Object No. 14		
2975.00 - 2976.65	2976.28	Initial search/verify hits
2975.02 - 2976.67	2976.29	Track initiation
2975.12 - 2976.77	2976.41	Early track
2977.52 - 2979.17	2978.92	Track while scan
2980.65 - 2982.30	2981.91	Drop track while scan

— continued —

Table 3.1 (continued)

ENGAGEMENT TIME (Sec)	Model Times	FUNCTION
Object No. 15		
2974.00 - 2975.65	2974.85	Initial search/verify hits
2974.02 - 2975.67	2974.95	Track initiation
2974.12 - 2975.77	2974.95	Early track
2976.52 - 2978.17	2977.57	Precision track
2976.52 - 2979.27	2977.79	MAR sent
2976.67 - 2980.47	2978.73	LCS sent
2978.72 - 2982.67	2981.57	Missile track acquired
2985.81 - 2986.86	2986.06	Missile burst confirmed
2985.81 - 2987.41	2986.36	Target track dropped
Object No. 16		
2973.00 - 2975.20	2974.26	Initial search/verify hits
2973.02 - 2975.22	2974.26	Track initiation
2973.12 - 2975.32	2974.39	Early track
2975.52 - 2977.72	2976.98	Track while scan
2978.63 - 2980.83	2979.02	Drop track while scan
Object No. 17		
2975.00 - 2977.20	2976.33	Initial search/verify hits
2975.02 - 2977.22	2976.33	Track initiation
2975.12 - 2977.32	2976.45	Early track
2977.52 - 2979.72	2978.96	Precision track
2977.52 - 2980.92	2979.06	MAR sent
2977.67 - 2982.02	2979.96	LCS sent
2979.72 - 2984.22	2982.81	Missile track acquired
2987.55 - 2990.13	2988.88	Missile burst confirmed
2987.55 - 2990.63	2989.09	Target track dropped

3.2 HARDWARE VALIDATION TEST RESULTS

The Hardware Validation test was performed according to the specifications contained in Section 5.2 of the test plan (TM-HU-048/502/00). The results of this test show that the MSI PEPE provides satisfactory performance for the execution of the PHSD tactical process on the MSI PEPE/CDC-7600/RIC equipment configuration. The specific conclusions that can be drawn from the Hardware Validation test are:

1. A single ensemble MSI PEPE configuration is capable of satisfying all deadline constraints for the PHSD process under heavy load conditions - more than 100 objects (targets + interceptors) in track.
2. The tactical programs execute (run) faster on the MSI design than on the IC design. (See Figures 1, 3, and 4.) The reasons for this are:
   a. The execution time of some of the PEPE instructions is faster in the MSI design (e.g. multiply instruction).
   b. Logic control for the parallel programs reside in MSI PEPE sequential control units rather than in the Host. This is a significant factor. In the IC design logic control for the parallel program was in the Host computer. Whenever a logic decision is required for the continued execution of the parallel process, the necessary data had to be sent to the Host over the PEPE/Host interface (e.g. channel). This operation would cause an I/O interrupt in the Host. The Host would respond to this interrupt by suspending (or terminating) the current task, read the data from PEPE, initiate the proper program to process the data, the program would create a PEPE response (decide which parallel instructions are to be executed next), initiate an I/O interrupt in order to send the information to PEPE, and then send the information over the PEPE/Host interface. If the frequency of this

interchange is high (as in the Pulse Allocation Program) and the I/O overhead in the Host is large compared to the amount of parallel code executed in each burst of parallel code, then the total execution time of the program will increase significantly. This situation occurs when the CDC-7600 is the Host computer for the IC PEPE.

The MSI design has eliminated all of this channel and I/O overhead by controlling the parallel process in PEPE rather than in the Host. This in turn reduces the execution time of the tactical programs, especially the Pulse Allocation Program (Figure 2).

c. The addition of the Associative Output Control unit in the MSI PEPE permits the concurrent operation of arithmetic and output functions. The total (elapsed) run time of a program can be reduced by partitioning the program into its arithmetic and output components and overlapping the operation of the arithmetic and associative output control units. This capability has caused a significant reduction in the run time of the Pulse Allocation Program (Figure 2).

d. The MSI design permits the operation of both the tracking and weapons functions on a single ensemble. This eliminates the requirement for inter-ensemble communications which in turn reduces the run time for some programs; e.g. target track processing (Figure 1), and eliminates the need for other programs; e.g. Interceptor Pulse Request Program.

3. In addition to having faster run times, the results of this test show run times of programs operating on the MSI PEPE are less sensitive to system load than the same program operating on the IC design. That is, the slope of the growth curve as a function of system load is less on the MSI design. This is especially true for the Target Track Processing and Pulse Allocation Programs.

The run time for the Target Track Processing (Kalman filter) is a function of system load in the IC design. The reason for this is the two ensemble configuration. The updated target state vectors must be passed to the weapons (Guidance) ensemble. Since the output time (from the track ensemble) is included in the program run time, it is load dependent. Since a single ensemble configuration is possible with the MSI design no inter-ensemble communication is required and thus the run time of the Target Track Processing Program is independent of system load for the MSI design (Figure 1).

Partitioning the Pulse Allocation algorithm into its arithmetic and output functions and implementing them on the Arithmetic Unit and Associative Output Unit not only reduces the program run time but makes the execution time less sensitive to system load (Figure 2).

4. The results of the test show that the potential parallelism is greater in the MSI design than the IC design. This is shown by the fact that the accumulation interval is longer in the MSI design than in the IC design (Figure 5).

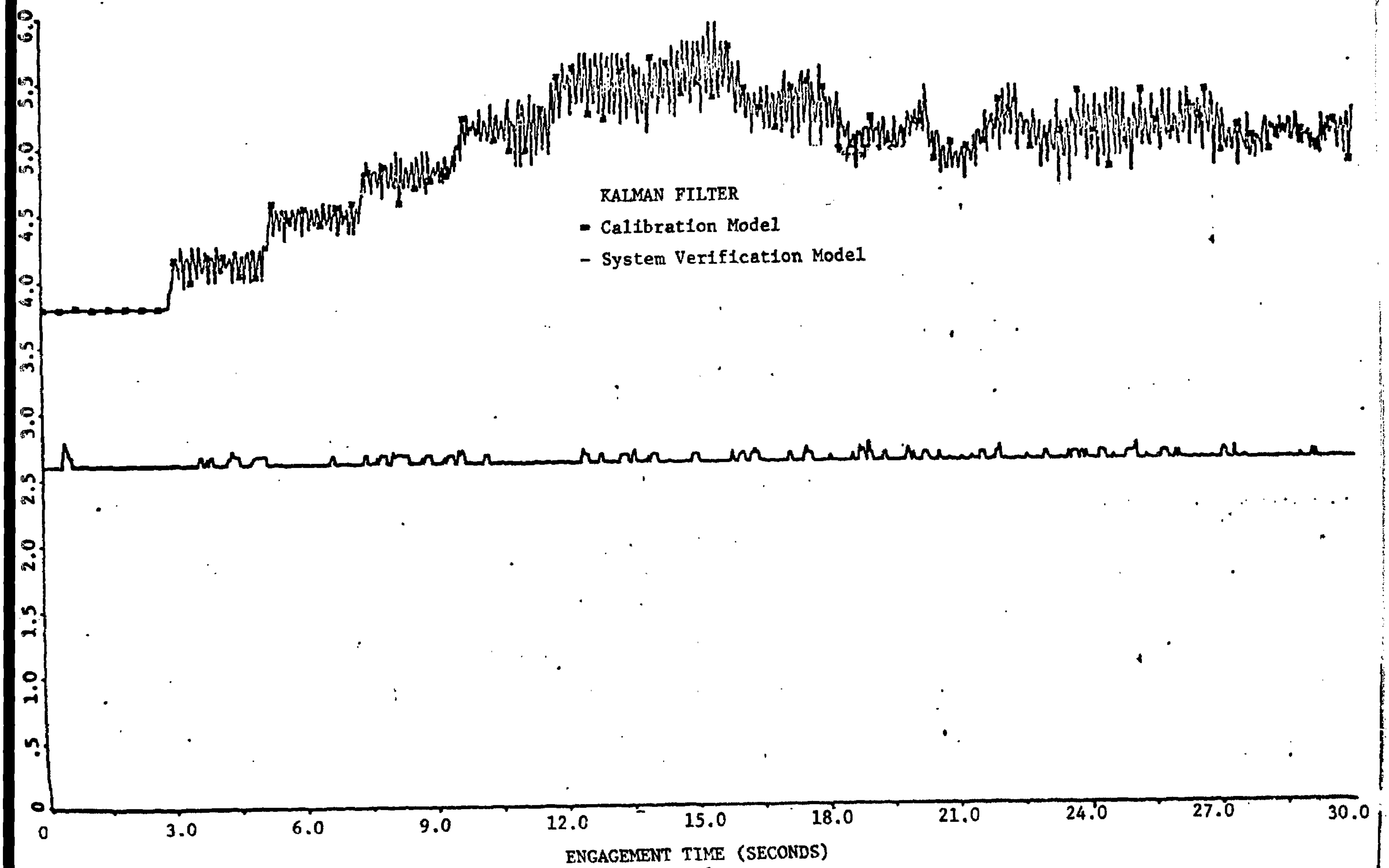
5. The results of this test show that the single ensemble MSI PEPE/CDC-7600/RIC equipment configuration has sufficient capacity for the PHSD problem even under heavy load conditions of more than 100 objects (targets + interceptors) in track at the same time. This can be seen from the utilization charts for the PEPE arithmetic and associative output control units and for the Host (Figures 6, 8, and 9 respectively). These results also show that both PEPE and the Host have significant reserve capacity which could be used for even heavier loads or enhanced tactical logic.

The threat for the Hardware Validation test contained 144 objects which entered the search volume in 12 waves of 12 RVs per wave at 2.1 second intervals. The interceptor capacity was increased to 150 missiles to cope with this threat. The engagement lasts 30 seconds. This test was run on both the Calibration and SVM models. A comparison of some results obtained from the Calibration and SVM models follows. However, before getting into the results of the test it should be remembered that the equipment configuration for the Calibration Model contained two PEPE ensembles of the IC (2 control units) design and that the configuration for the SVM model contains one PEPE ensemble of the MSI (3 control unit) design. It should also be remembered that the host computer for the Calibration Model is a special purpose computer which is conducive to instruction streaming whereas the host computer for the MSI PEPE, CDC-7600, is general purpose computer and less conducive to instruction streaming. Thus, one must be careful when comparing the results from the Calibration Model with those obtained from the System Verification Model.

3.2.1 Target Track Processing (Kalman Filter)

Figure 1 shows the execution time of the Target Track Processing Program for the Hardware Validation test. It shows the execution time for the program from both the Calibration and SVM models under identical conditions. As can be seen from Figure 1, the run time (sequential + parallel) of the program in the Calibration Model remains constant at about 3.8 ms for the first three seconds of the engagement. After that time the updated state vector for the targets must be passed to the Guidance ensemble. The uniformly arriving threat causes a linear increase in the program run time up to approximately 6 ms at about 15 seconds into the engagement. There are approximately 80 objects in track at this point. After this time (15 seconds) the run time of the program gradually decreases as successful kills are made.

The execution time on the SVM model, on the other hand, is constant throughout the entire mission and significantely lower with an execution time of about 2.6 ms. The small ripples in the program run time are caused by the execution of track initiation and state vector updates for the search correlation program. The track initiation program has been combined with the Kalman filter in the System Verification Model and thus whenever track initiation are performed there is a slight increase in the run time of the Target Track Processing Program. This causes the larger "bumps" in the curve.


KALMAN FILTER
▪ Calibration Model
– System Verification Model
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
ENGAGEMENT TIME (SECONDS)
Figure 1

3.2.2 Pulse Allocation

Figure 2 presents a comparison of the run times for the Pulse Allocation Program for the Hardware Validation test. It shows the run time for the Calibration model and the SVM model. As can be seen from Figure 2 the run time for the program in the SVM model is significantly less than for the Calibration model. In addition, it is less sensitive to system load. The two most significant reasons for the improved performance in the System Verification Model are: (1) the addition of the Associative Output Control Unit in the MSI PEPE permits an overlapping of the arithmetic and output functions in pulse allocation, and (2) placing logic control of the parallel process in PEPE greately reduces the communication frequency between PEPE and the Host.

RUN TIME - PULSE ALLOCATION PROGRAM

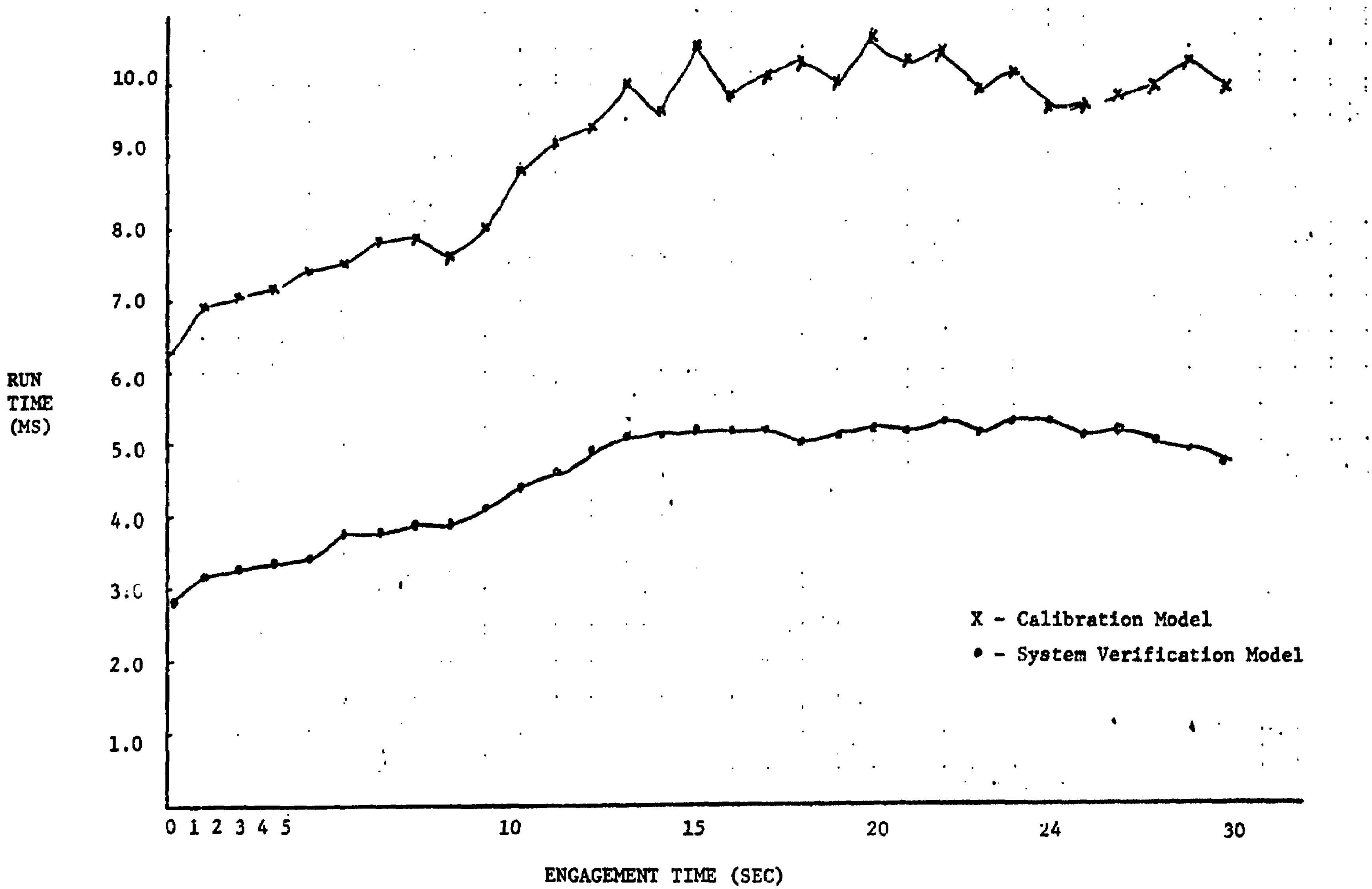
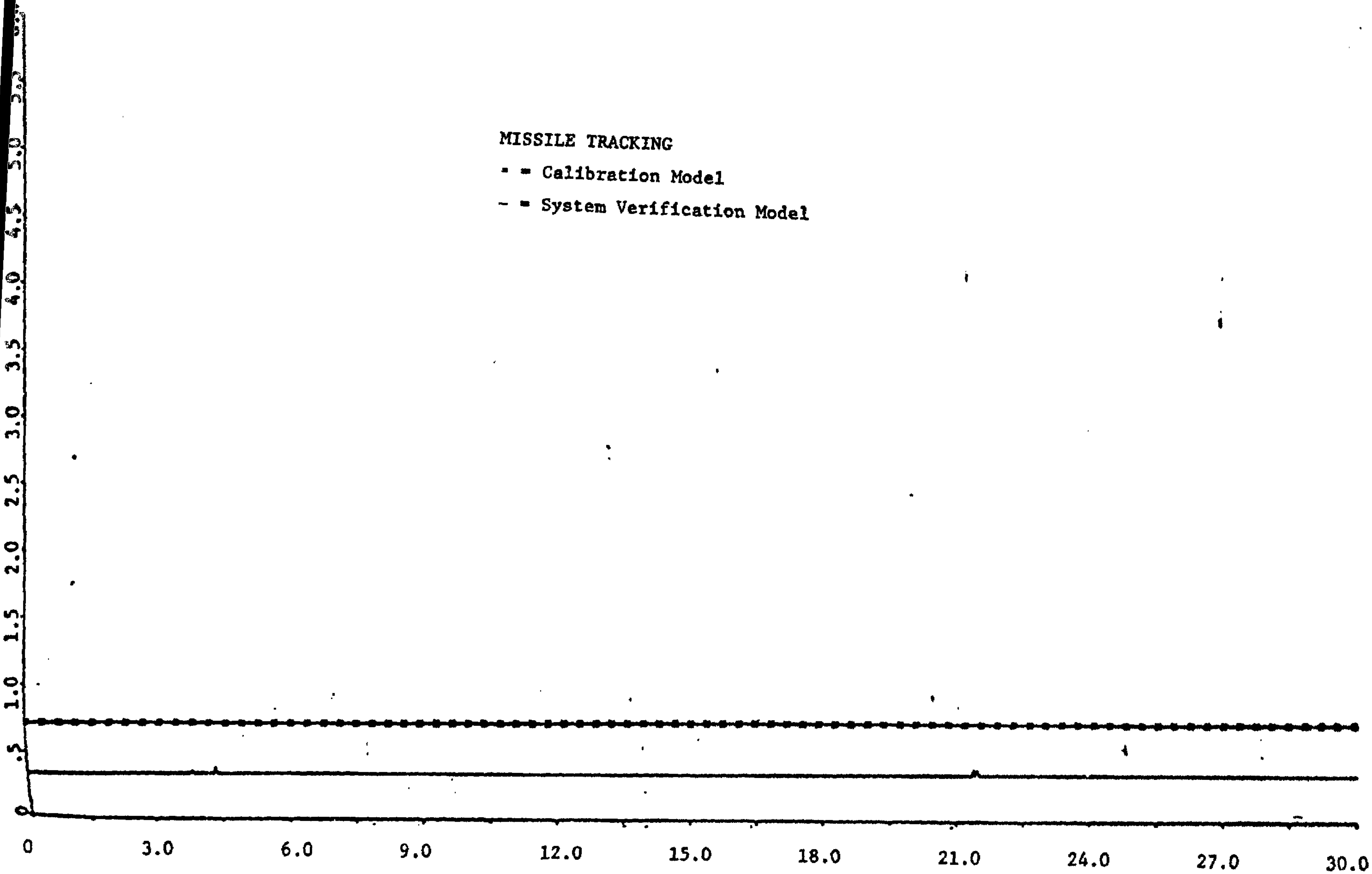


Figure 2

3.2.3 Interceptor Track Processing (Missile Tracking)

Figure 3 presents a comparison of the run time for the Interceptor Track Processing Program for the Hardware Validation test. The improved performance by the SVM model is a direct result of faster instructions in the MSI PEPE, especially for the floating point multiply.

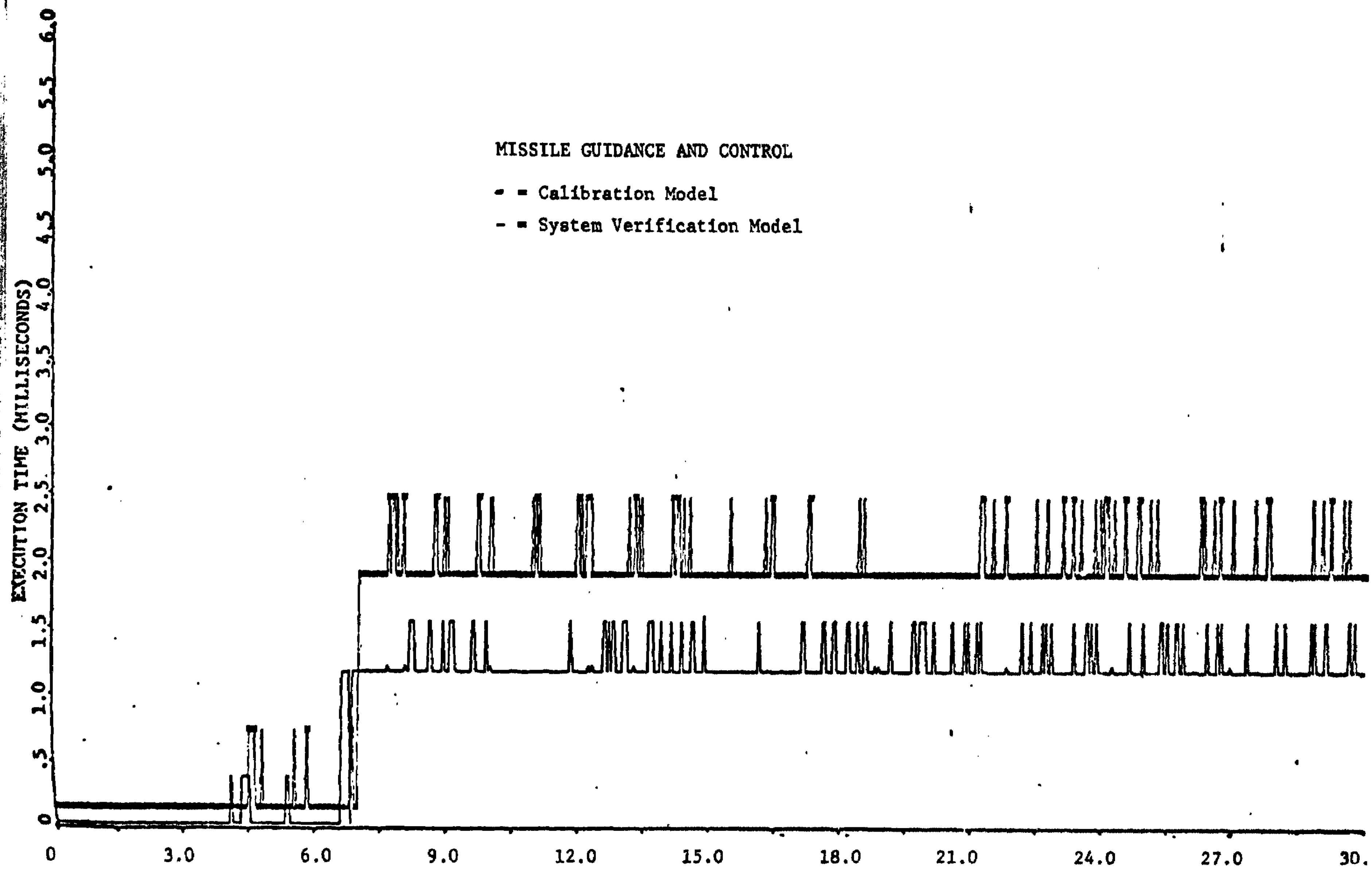


MISSILE TRACKING
• = Calibration Model
– = System Verification Model
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
ENGAGEMENT TIME (SECONDS)

Figure 3

3.2.4 Missile Guidance and Control

The results of the Hardware Validation test for the Missile Guidance and Control Program are presented in Figure 4. This data shows that the program run time is significantly lower for the SVM. Most of the improvement is the result of a faster multiply instruction in the MSI PEPE.


MISSILE GUIDANCE AND CONTROL
- = Calibration Model
- = System Verification Model
EXECUTION TIME (MILLISECONDS)
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.
ENGAGEMENT TIME (SECONDS)
Figure 4

3.2.5 PEPE Accumulation Interval

Figure 5 presents a comparison of the PEPE accumulation interval for the Hardware Validation test. This figure shows that the accumulation interval for the System Verification model is approximately 4 ms (or 10%) longer than the accumulation interval for the Calibration Model. Since the length of the accumulation interval is a measure of potential parallelism and the longer the accumulation interval the greater the potential parallelism, the performance characteristics of the MSI PEPE are superior to those of the IC design.

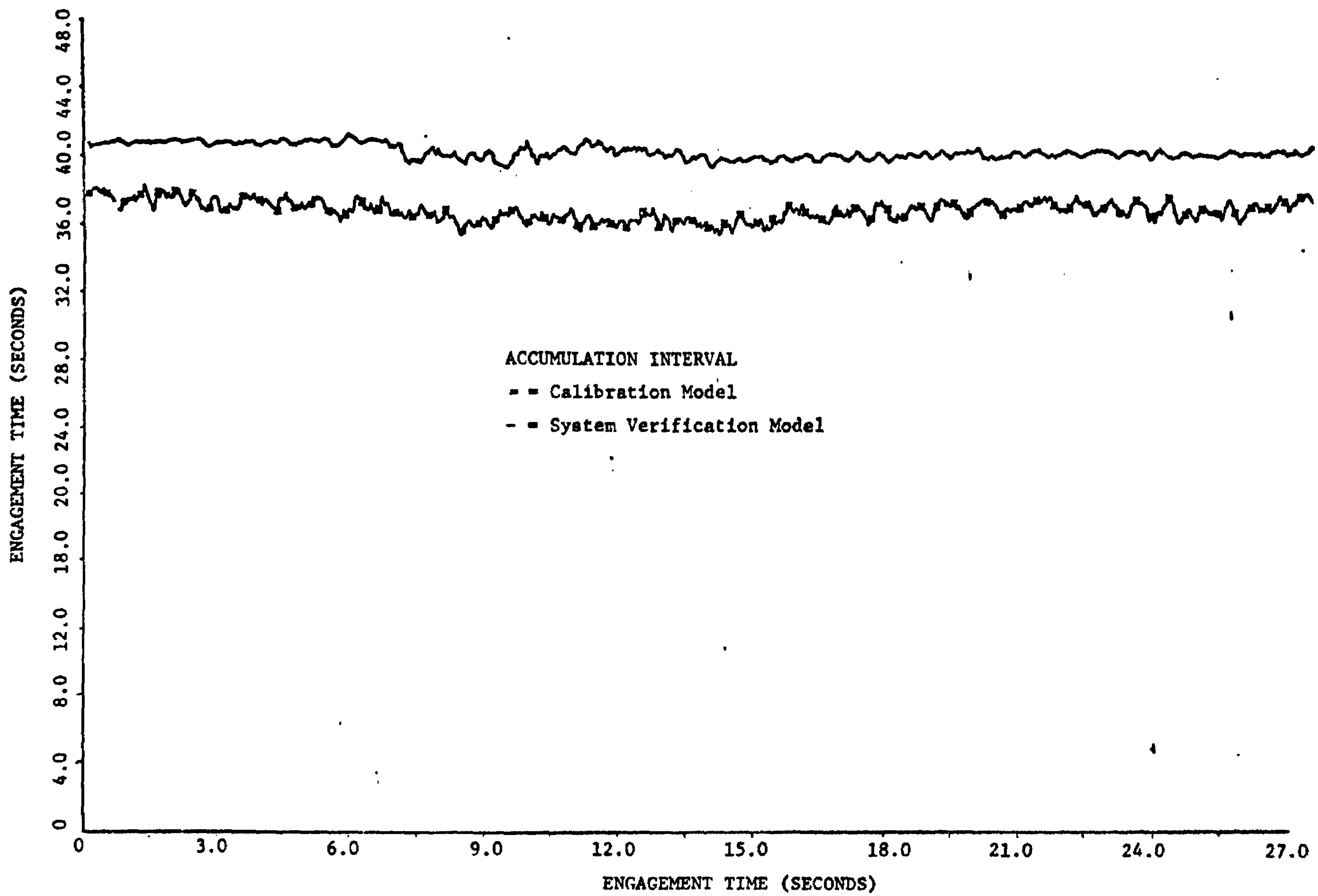

ENGAGEMENT TIME (SECONDS)
0
4.0
8.0
12.0
18.0
20.0
24.0
28.0
32.0
36.0
40.0
44.0
48.0
ACCUMULATION INTERVAL
= = Calibration Model
- = System Verification Model
0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
ENGAGEMENT TIME (SECONDS)

Figure 5

3.2.6 Resource Utilization - System Verification Model

Resource utilization measurements were made on three components of the System Verification Model: the Arithmetic Control Unit, the Associative Output Control Unit, and the CDC-7600 Host. The System Verification Model resource utilization is defined to be the amount (percentage) of time that the component is busy during some time interval. The time interval selected for the SVM Model was 100 ms.

Figure 6 shows the ACU utilization during the Hardware Validation test. It shows the average ACU utilization for each second during the 30 second test. The track (target + interceptor) load has also been plotted in Figure 6 so that ACU utilization can be compared with track load.

The average ACU utilization for the entire test was 18.6%. The maximum utilization during any one 100 ms interval was 72.8%. This occurred once during the test. Figure 7 shows how the 100 ms ACU utilization are distributed. This figure shows, for example, that in 70% of the 100 ms intervals, the ACU utilization was between 10 and 10.99%. Less than 10% of the 100 ms intervals have an utilization greater than 30%, therefore, one can conclude that the ACU has significant reserve capacity for the case in which the tracking and weapons functions for the PHSD tactical process are executied in a single ensemble and the track load reaches 95 objects. This reserve capacity could be used for even larger target loads and/or enhanced algorithms.

An examination of the data contained in Figure 6 shows that there is very little relation between the track load and the ACU utilization. Very large increases in the track load have little or no affect on the ACU utilization. For example, the track load increases by a factor of 7 between 3rd and 15th second of the mission, however, the average ACU utilization shows very little increase.

The fluctuations in the ACU utilization are caused by the weapon functions which operate on a more or less irregular basis (at least when compared to the track functions). The ACU utilization can increase significantly when the track and weapons functions operate in the same cycle. For example, the arrival of the first wave of objects causes a series of

weapons functions to be executed at the third second of the mission. This caused the ACU utilization to increase from 10% to about 22%. The execution frequency of the weapons functions increases with mission time and therefore we have a gradual increase in the ACU utilization.

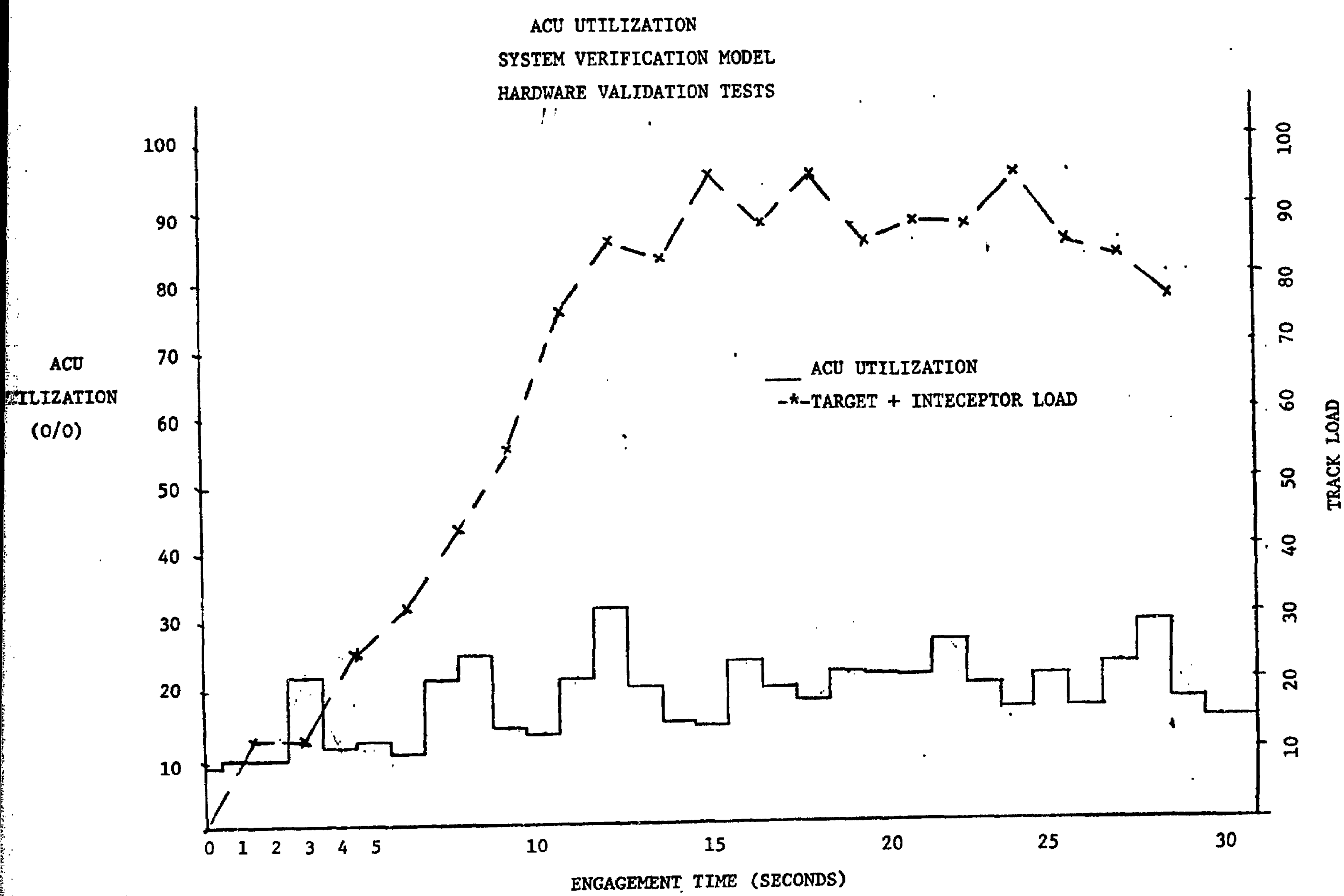

ACU UTILIZATION
SYSTEM VERIFICATION MODEL
HARDWARE VALIDATION TESTS
ACU
ILIZATION
(0/0)
100
90
80
70
60
50
40
30
20
10
0 1 2 3 4 5 10 15 20 25 30
ENGAGEMENT TIME (SECONDS)
TRACK LOAD
ACU UTILIZATION
-*-TARGET + INTECEPTOR LOAD

Figure 6

DISTRIBUTION OF ACU UTILIZATION

HARDWARE VALIDATION TEST 1

(100 MS INTERVAL)

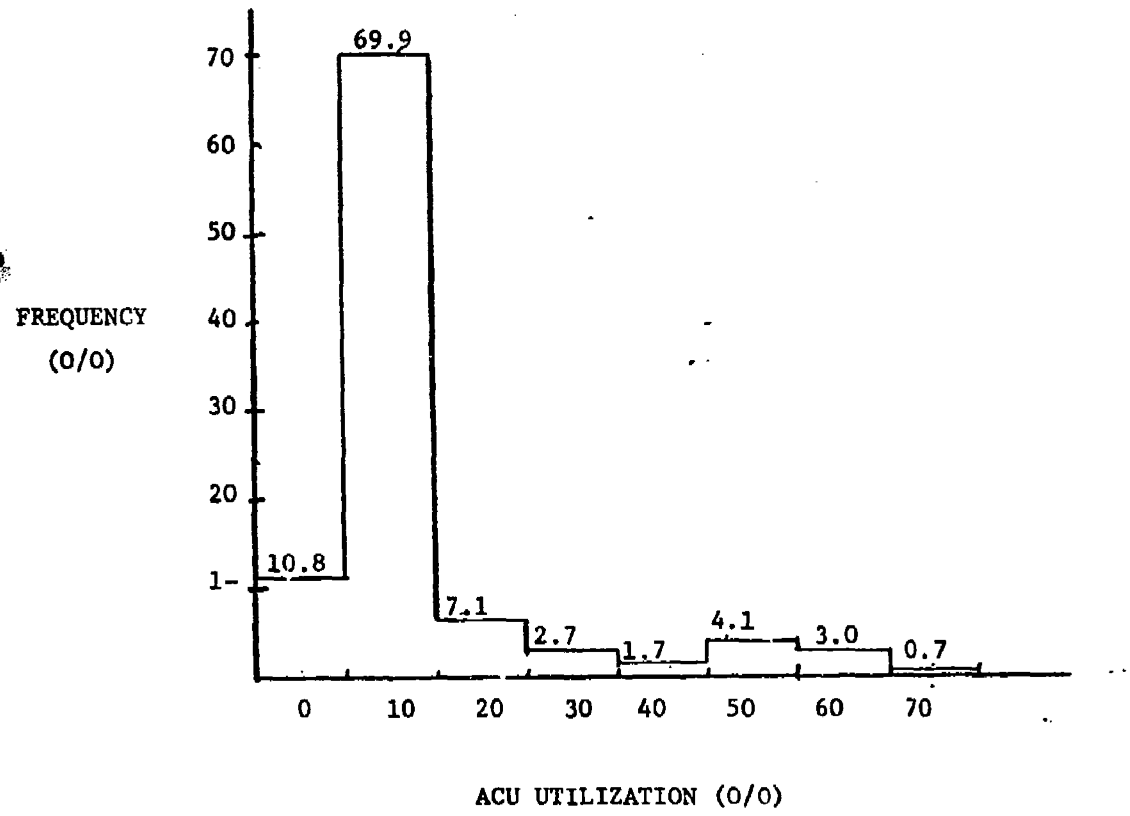


Figure 7

Figure 8 shows the utilization of the Associative Output Unit for the Hardware Validation test. As can be seen from Figure 8, the utilization of the AOU remains low and almost constant throughout the entire test. It starts at less than 10% and gradually increaes to slightly more than 15%. The average utilization is 11.3%. The maximum utilization during any one 100 ms interval is 16.7%. This occurred twice during the test.

Comparing the AOU utilization with the work load we can see that it is almost independent of the track work load.

It is clear from Figure 8 that the AOU has significant reserve capacity for other functions.

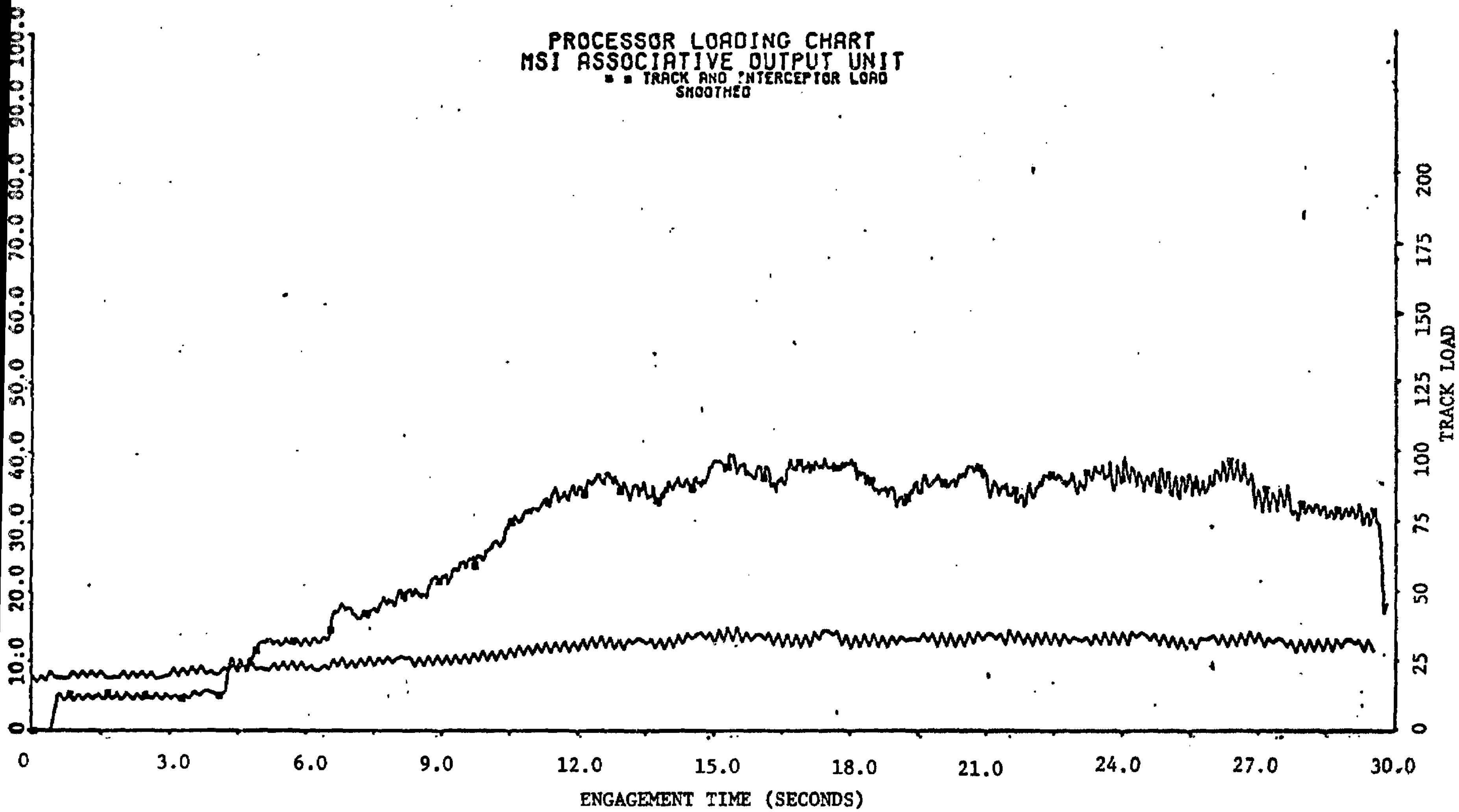

PROCESSOR LOADING CHART
MSI ASSOCIATIVE OUTPUT UNIT
TRACK AND INTERCEPTOR LOAD
SMOOTHED
0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
0 25 50 75 100 125 150 175 200
TRACK LOAD
0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0 30.0
ENGAGEMENT TIME (SECONDS)

Figure 8

The utilization of the CDC-7600 Host during the Hardware Validation test is shown in Figure 9. The Host utilization is very low and not dependent on the track load. The average utilization of the test was 0.6%. The maximum utilization was 2.8%. It occurred once during the test. The primary function of the Host in this configuration was the execution of the real time operating system. The Host has significant reserve capacity for other functions.

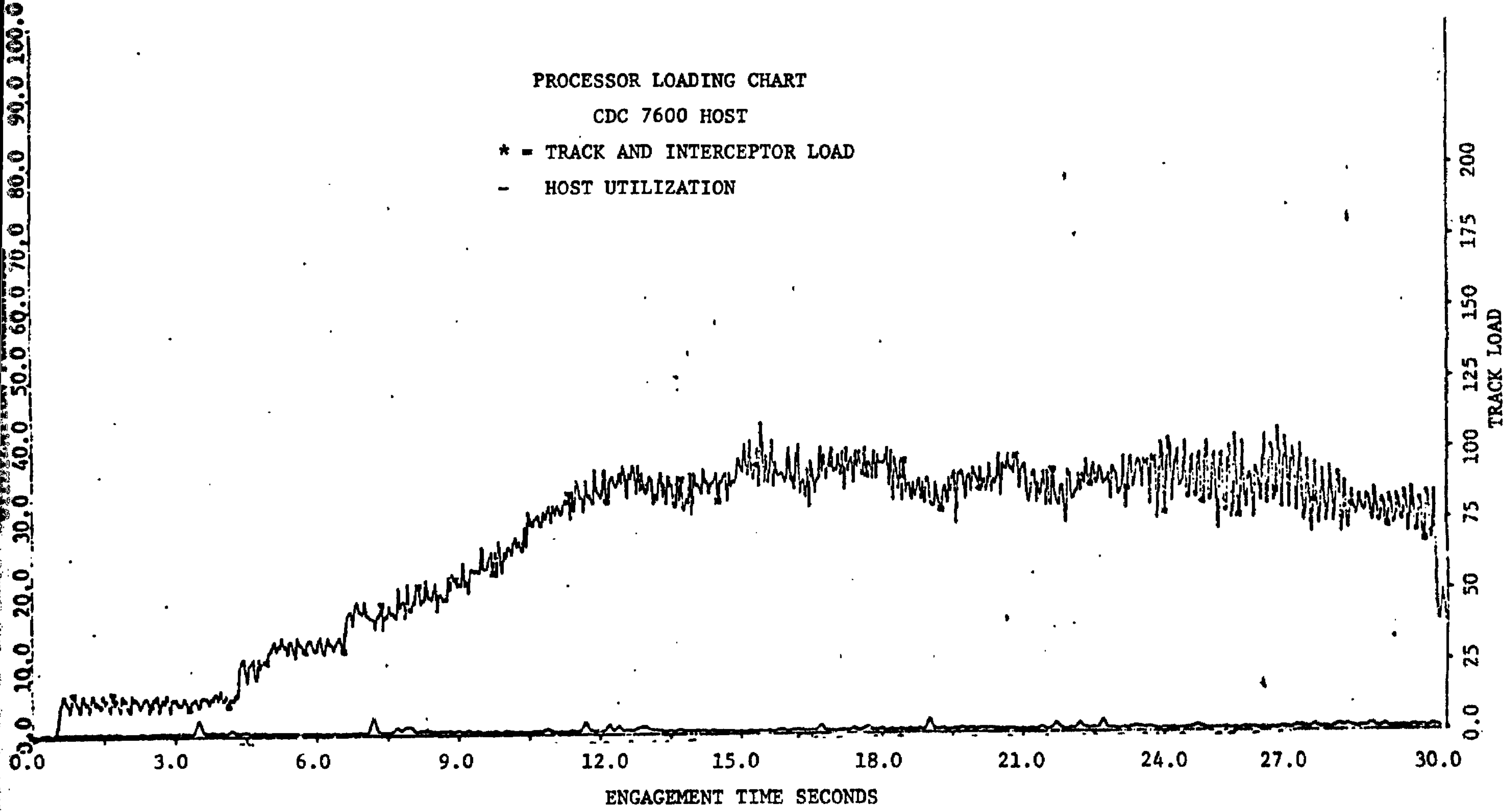

PROCESSOR LOADING CHART
CDC 7600 HOST
* = TRACK AND INTERCEPTOR LOAD
- HOST UTILIZATION
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
0.0 25 50 75 100 125 150 175 200
TRACK LOAD
0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0 30.0
ENGAGEMENT TIME SECONDS

Figure 9